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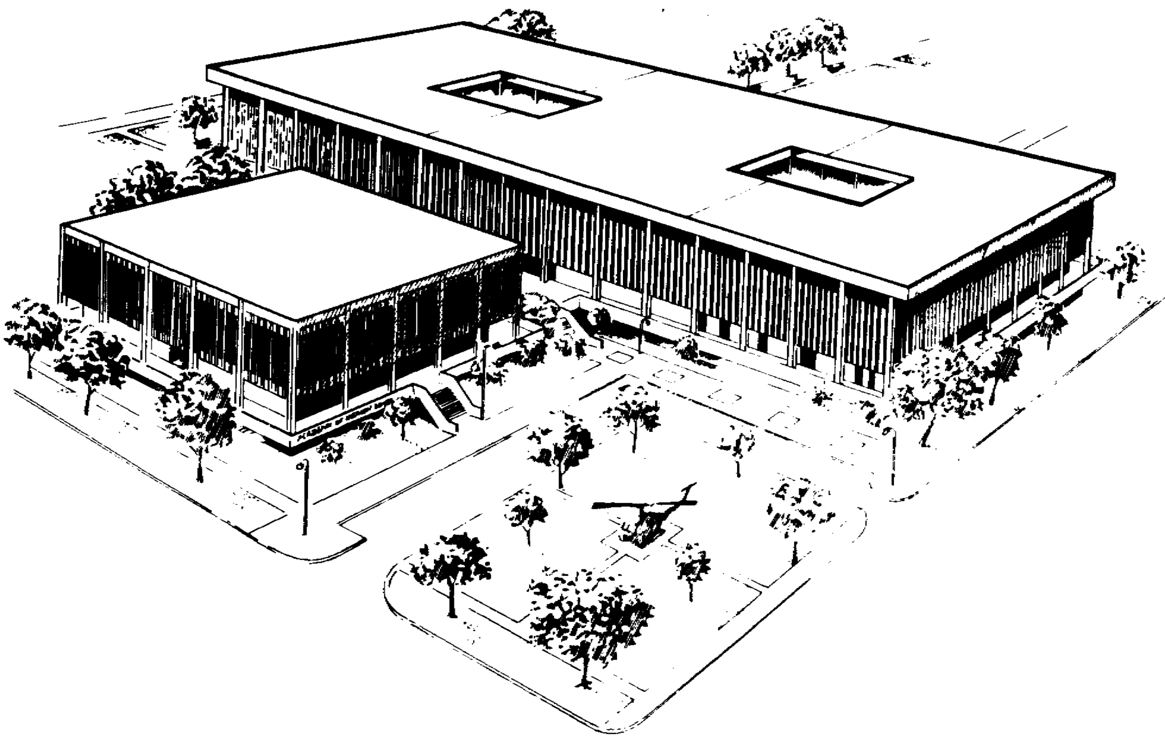

WASTEWATER TREATMENT

SUBCOURSE MD0161 EDITION 100

DEVELOPMENT

This subcourse is approved for resident and correspondence course instruction. It reflects the current thought of the Academy of Health Sciences and conforms to printed Department of the Army doctrine as closely as currently possible. Development and progress render such doctrine continuously subject to change.

When used in this publication, words such as "he," "him," "his," and "men" 'are intended to include both the masculine and feminine genders, unless specifically stated otherwise or when obvious in context.

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ADMINISTRATION

Students who desire credit hours for this correspondence subcourse must meet eligibility requirements and must enroll through the Nonresident Instruction Branch of the U.S. Army Medical Department Center and School (AMEDDC&S).

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CORRESPONDENCE COURSE OF
THE U.S. ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL

SUBCOURSE MD0161

WASTEWATER TREATMENT

INTRODUCTION

Primitive man was confronted with the problem of waste disposal; however, the problem was rather simple in primeval societies. When wastes became unpleasant because of odors and insects, people would simply move away from them. People were few and land was plentiful.

As civilizations developed, man began to realize the need for sanitary disposal of human wastes. Ancient civilizations of the Old World have left ruins of wastewater disposal systems dating as far back as 4,000 B.C. Both the Greeks and the Romans built comprehensive wastewater systems, parts of which are still in operation today.

With the fall of the Roman Empire, the civilization of European retrogressed into the "Dark Ages." In cities and villages, people disposed of excreta and household wastes by throwing them from the window or doorstep into the courtyard or street. It was during this period of history that Europe was swept by great epidemics of typhoid fever, cholera, dysentery, and other diseases. As the more astute members of society began to associate filth with disease, laws were passed pertaining to waste and refuse disposal. Thus, the environment in urban areas was greatly improved and the incidence of disease was diminished.

In the United States, as long as we remained a country of small towns and farms, waste disposal was not a serious problem. But the country grew rapidly. As wastes began to pollute our inland waters, the quality of our water supplies was endangered. In 1855, our first wastewater systems were built in the cities of Boston and Chicago. Today, the vast majority of our organized communities have wastewater systems. With continued improvements in technology and stricter enforcement of antipollution legislation, the quality of our environment can be greatly improved. The Army also strives to protect the environment and soldiers from the spread of diseases by training its soldiers in the proper and safe way to dispose of waste.

Liquid and solid wastes accumulate rapidly during a normal day. Under field conditions, this accumulation can readily become a breeding ground for insects and diseases. Since our fighting strength needs to remain healthy to protect, defend, and serve our country, waste disposal methods need to be effective, efficient, and safe.

In this subcourse, you will be introduced to the fundamentals of wastewater disposal, suitable wastewater treatment systems at the installation and in the field, and ways to construct improvised wastewater disposal devices for field use.

This subcourse consists of three lessons and an examination. The lessons are:

Lesson 1. Introduction to Wastewater Treatment.

Lesson 2. Wastewater Treatment Plant Operation.

Lesson 3. Field Waste Disposal Methods.

Credit Awarded:

Upon successful completion of this subcourse, you will be awarded 6 credit hours.

Materials Furnished:

Materials provided include this booklet, an examination answer sheet, and an envelope. Answer sheets are not provided for individual lessons in this subcourse because you are to grade your own lessons. Exercises and solutions for all lessons are contained in this booklet. *You must furnish a #2 pencil*.

Procedures for Subcourse Completion:

You are encouraged to complete the subcourse lesson by lesson. When you have completed all of the lessons to your satisfaction, fill out the examination answer sheet and mail it to the AMEDDC&S, along with the Student Comment Sheet, in the envelope provided. *Be sure that your social security number is on all correspondence sent to the AMEDDC&S*. You will be notified by return mail of the examination results. Your grade on the examination will be your rating for the subcourse.

Study Suggestions:

Here are some suggestions that may be helpful to you in completing this subcourse:

--Read and study each lesson carefully.

--Complete the subcourse lesson by lesson. After completing each lesson, work the exercises at the end of the lesson, marking your answers in this booklet.

--After completing each set of lesson exercises, compare your answers with those on the solution sheet, which follows the exercises. If you have answered an exercise incorrectly, check the reference cited after the answer on the solution sheet to determine why your response was not the correct one.

--As you successfully complete each lesson, go on to the next. When you have completed all of the lessons, complete the examination. Mark your answers in this booklet; then transfer your responses to the examination answer sheet using a #2 pencil and mail it to the AMEDDC&S for grading.

Student Comment Sheet:

Be sure to provide us with your suggestions and criticisms by filling out the Student Comment Sheet (found at the back of this booklet) and returning it to us with your examination answer sheet. Please review this comment sheet before studying this subcourse. In this way, you will help us to improve the quality of this subcourse.

LESSON ASSIGNMENT

LESSON 1 Introduction to Wastewater Treatment.

TEXT ASSIGNMENT Paragraphs 1-1 through 1-17.

LESSON OBJECTIVES After completing this lesson, you should be able to:

1-1. Select the statement that best describes the aspects of wastewater treatment plants that are significant to public health.

1-2. Select the statement which best describes the major elements of sanitary wastewater and the percentage of each.

1-3. Select the statement that correctly describes the collection, treatment, and disposal systems for wastewater.

1-4. Select the appropriate type of construction, operation, and maintenance of septic tank systems for user needs.

SUGGESTION After studying the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 1

INTRODUCTION TO WASTEWATER TREATMENT

Section I. WASTEWATER FUNDAMENTALS

1-1. GENERAL

Wastewater is used water (liquid) and solids that flow to and through the wastewater collection system. A *wastewater collection system* consists of all facilities for the collection, transportation, pumping, treatment, and disposal of wastewater.

a. *Domestic wastewater* or *sanitary domestic wastewater* is the "used" water originating from businesses, houses, and installations and similar buildings inhabited by people.

b. *Storm drainage* consists of rain water, street wash, and flood waters.

c. *Combined wastewater* is domestic wastewater mixed with storm drainage.

d. *Industrial wastewater* is the wastewater discharged from an industrial process, such as dyeing or papermaking.

1-2. NEED FOR SAFE DISPOSAL OF WASTEWATER

a. Safe disposal of all human and domestic wastes is necessary to protect the health of the individual (soldier or civilian), family, and community and to prevent waste products in our environment. Wastewater may contain fecal matter, industrial wastes such as oils and emulsions, alkalis and strong acids), organic material, and other dissolved solids. For satisfactory results, such wastes must be disposed of so that they will NOT:

(1) Contaminate any drinking water supply by such means as biological organisms, radiological and chemical agents, or physical material.

(2) Give rise to a public health hazard by being accessible to insects, rodents, or other possible carriers that may come into contact with food or drinking water.

(3) Give rise to public health hazards by being accessible to children.

(4) Violate international, national, or local laws or regulations governing water pollution or wastewater disposal.

(5) Pollute or contaminate the waters of any bathing beach, shellfish breeding ground, stream used for public or domestic water supply, or recreational area.

(6) Give rise to a nuisance due to odor or unsightly appearance.

b. To reach these objectives, those responsible for wastewater disposal must collect the wastewater and change it from a smelly, infectious, unsightly waste into some kind of harmless, inoffensive substance. This involves passing the wastewater through a wastewater treatment device, works, or plant. Responsibilities and means for wastewater treatment and disposal are discussed in the remainder of this text.

1-3. RESPONSIBILITIES FOR WASTEWATER DISPOSAL AT MILITARY INSTALLATIONS

a. **The Department of the Army.** The Department of the Army (DA) is responsible for the health of Army personnel wherever they may be.

b. **The Corps of Engineers.** The Corps of Engineers (COE) is responsible for the construction, operation, and maintenance of all wastewater treatment facilities on Army installations. Actual construction of the wastewater facilities is usually carried out by civilian consulting and construction engineering firms under the direct supervision of the COE. The operation and maintenance personnel are also civilians, who are trained and experienced technicians and engineers. They work under the direct supervision of the installation engineer officer.

c. **The Army Medical Department.**

(1) Consult and advise. The Army Medical Department (AMEDD) acts in a consulting and advisory capacity in the design, construction, operation, and maintenance of wastewater facilities.

(2) Survey, inspect, regulate, and report. The AMEDD must at all times know that wastewater is properly collected, adequately treated, and promptly removed, and finally disposed of in such a manner as to create no nuisance conditions or health hazards either to military or civilian personnel. This requires:

(a) Regular and frequent sanitary surveys and inspections of wastewater systems and wastewater treatment plant operations.

(b) Checking the training, experience, and efficiency of operation, maintenance, and laboratory personnel.

(c) Performing sufficient laboratory tests to regulate treatment processes; thus, controlling the processes.

(d) Reporting operation data and test results to provide an accurate record of treatment efficiency.

(3) Investigate. The surgeon of a command (Director of Health Services of an installation) exercises supervisory responsibilities through the supporting preventive medicine unit or the medical department activity (MEDDAC) preventive medicine activity. The unit and activity have assigned sanitary engineers and environmental science officers who are qualified to conduct investigations of wastewater treatment facilities and make recommendations to the operating engineer personnel. The environmental health specialist assists the professional members by collecting samples for analysis and recording observations made during investigations.

(4) Follow Federal, state, and local health laws. The sanitation problems of civilian communities near military installations are of considerable importance. The post may also be located on land not owned by the Federal Government. Therefore, the surgeon of a command must keep abreast of not only Federal, but also state and local health laws pertaining to stream pollution and waste disposal in areas occupied by the command he serves. By knowing pertinent laws, the surgeon can help prevent creation of nuisances and health hazards and unlawful disposal of wastewater and other wastes.

d. **Commander.** The commander is responsible for health and welfare of the soldiers under his care. He must ensure that the facilities and surrounding area or field conditions are as safe or sanitary as possible. The commander must ensure that his field sanitation team is trained and trains unit personnel to follow established procedures in the construction and operation of waste facilities so as to dispose of waste properly.

e. **Field Sanitation Team.** The field sanitation team (FST) is responsible for the basic sanitation and for the protection and training of unit personnel in waste disposal. The FST supervises the construction and maintenance of garbage pits, soakage pits, field latrines, and field urinals. The team assists the commander in inspections of sanitation and waste disposal.

f. **Individual Soldiers.** Each soldier is responsible for personal hygiene and for following established sanitation and waste disposal policy and procedures.

1-4. PREVIOUS PURIFICATION PROCESSES

Streams and other natural bodies of water are capable of self-purification using the natural settling and anaerobic and aerobic decomposition. Most wastewater plant processes are about the same as natural processes, except that they are confined, controlled, and intensified. For many years, some municipal wastewater systems were essentially transportation systems by which raw wastewater was carried from the point of origin to a body of water where it was disposed of by dilution. Presumably, the degree of dilution was considered sufficient to permit natural purification. In practice, however, the amount of pollution discharged into natural bodies of water was far in excess of their self-purification capabilities. Purification by dilution requires about 20 to 40 times as much water as wastewater. With ever-increasing metropolitan populations, such vast quantities of our unpolluted water are no longer available. Accordingly, Federal water pollution laws now prohibit the discharging of untreated effluents into navigable or interstate waters.

1-5. CHARACTERISTICS OF WASTEWATER

a. **Physical Characteristics.** These characteristics are concerned with detection of wastewater by using the physical senses: temperature, odor, color, and feel of solid material. Fresh wastewater is turbid, grayish-white in color, and has a musty odor. Small particles of feces and paper are visible in the waste stream, but these will rapidly settle if the wastewater is quiescent. Fresh wastewater becomes stale in 2 to 6 hours, depending upon temperature, nature of materials present, and the addition of oxygen through turbulent flow. Warm wastewater becomes stale more rapidly than cold wastewater. The addition of oxygen helps extend the time that wastewater will remain fresh. Stale wastewater is dark brown to black and has a pronounced hydrogen sulfide (rotten egg) odor. See Table 1-1 for significant colors of wastewater. Frequently, gas bubbles will evolve from the surface. Carbon dioxide (a product of aerobic decomposition and necessary for the support of algae growth) and sometimes methane (a product of anaerobic decomposition which occurs during wastewater digestion) are found in wastewater.

COLOR	PROBLEM INDICATED
Gray	None
Green, yellow, or other	Industrial wastes not pretreated (paints, etc.)
Red	Blood, other industrial wastes, or TNT complex
Red or other soil color	Surface runoff into influent, also industrial flows
Dark brown to black	Hydrogen sulfide
Black	Septic conditions or industrial flows

Table 1-1. Significant colors in wastewater.

b. **Chemical Characteristics.** The chemical characteristics of wastewater include: dissolved oxygen, pH, oxygen demand, toxic material, and nutrients.

Wastewater is called strong or weak depending upon the amount of oxygen that is required to oxidize and stabilize it.

(1) Dissolved oxygen. Fresh water normally contains dissolved oxygen (DO) in amounts ranging from about six to about 12 parts per million (ppm) parts of water. Fresh wastewater normally will have a DO content within or just below this range. As wastewater becomes stale, the DO is consumed. Thus, the DO of wastewater is a measure of its freshness. Oxygen in wastewater is necessary to support aerobic bacterial action.

(2) Biochemical oxygen demand. The organic matter in wastewater, primarily of human or food origin, is unstable and readily decomposed and oxidized by biological or chemical agents to form more stable substances. This process requires oxygen. The stronger the wastewater, the greater the amount of oxygen that is required. The biochemical oxygen demand (BOD) is defined as the quantity of oxygen required for the biochemical oxidation of the decomposable (organic) matter at a given temperature within a given time, usually 5 days at 20°C (68°F). It is normally expressed as the 5-day BOD in milligrams per liter (mg/l) or ppm. Average domestic wastewater varies from approximately 150 to 250 mg/l (ppm) 5-day BOD.

c. **Biological Characteristics.** Bacteria, viruses, and parasites make up the biological characteristics of wastewater. Wastewater contains vast quantities of bacteria and other organisms that originate in discharged wastes. The feeding activities of these organisms assist in decomposing wastewater. Aerobic bacteria decompose organic matter in the presence of free oxygen. Anaerobic bacteria decompose organic matter that is shut off from free oxygen, such as in the interior of a mass of feces or a dead body. The products of anaerobic decomposition have an extremely unpleasant odor. Matter in which this condition exists is said to be septic. A large number of the bacteria in wastewater are coliform bacteria -- those found in the digestive tract of normal humans. While most of these bacteria are harmless, pathogens will usually be present in wastewater containing the discharges of many persons. It is these relatively few pathogenic organisms that pose the greatest public health hazard. Wastewater that is not properly treated may eventually find its way into a community water source and spread waterborne diseases.

d. **Composition of Wastewater.** The composition of wastewater varies from hour to hour, day to day, and season to season; but its average composition can be determined for a given period. Normally, wastewater is 99.9 percent water by weight. *The remaining 0.1 percent (1,000 ppm) is organic and mineral matter* (dissolved, suspended, organic, and inorganic solids). Most of the mineral matter consists of salts from the water supply, urine, meat and vegetable extracts, and permissible acids and alkalies from industries. The organic matter, primarily from human or food origin, is unstable and readily decomposed and oxidized by biological or chemical agents to form more stable substances. The total organic and mineral matter in wastewater comprise about 0.1 percent by weight. This matter is further classified as filterable and nonfiltrable residue.

(1) Filterable residuals. Filterable residues comprise about 60 percent of the total residue. These substances in solution are mainly inorganic compounds such as mineral salts, many of which are not removed by conventional wastewater treatment methods.

(2) Nonfiltrable residues. Nonfiltrable residues account for about 40 percent of the total residue. Typical residues found in domestic wastewater are feces, toilet paper, grease, food scraps, hair, and dirt. Considerable quantities of grit will infiltrate into the wastewater system. Domestic wastewater will also contain refuse which should have been disposed of in some other way but which has, accidentally or purposely, been placed in the wastewater system. Examples include broom straws, rags, towels, bandages, sanitary napkins, sticks, match stems, cigarette and cigar stubs, tobacco cans and pipes, denture plates, condoms, dead animals, and a variety of other domestic and industrial materials. Nonfiltrable residues are further subdivided into floating, settleable, and nonsettleable residues. *Settleable residues are those that will settle to the bottom in about one hour under relatively quiet conditions*. The strength of nonfiltrable residue is determined by filtering a given quantity of wastewater and drying and weighing the filtrate. Nonfiltrable residues are expressed in milligrams per liter (mg/l, or ppm).

1-6. QUANTITY OF WASTEWATER

The organic strength of sanitary wastewater varies through wide ranges. Usually, wastewater strength is greatest when the wastewater rate of flow is highest and lowest when the flow rate is lowest. The strongest wastewater is normally produced during the morning hours and the weakest at night. Water infiltration into sewers during rainy weather will dilute the wastewater, thus making it weaker.

a. **Per Capita Production.** For comparison purposes, wastewater flow is commonly reported as average daily flow per person. The variation may be from as much as 200 gallons per capita per day in some large cities to as low as 25 gallons per capita per day in small communities. Reports from many of the permanent and semipermanent military camps show a much smaller variation in proportion to population. An average figure is approximately from 70 to 100 gallons per capita per day, or about 70 percent of the domestic water consumption under routine conditions.

b. **Hourly Flow.** The volume of a domestic wastewater varies widely during each day. The period of peak flow, usually 200 to 300 percent of the average flow, lasts for a few hours after the period of peak water consumption preceding and following breakfast. Secondary periods of high flow normally occur in the early afternoon and again for a few hours in the evening. Minimum flow occurs after 2400 hours to approximately 0600 hours and may be as low as 10 percent of the average daily flow. These wide variations in flow are not as pronounced in large cities, but are readily apparent at Army camps and in small communities that follow a normal activity pattern.

Section II. WASTEWATER TREATMENT AND DISPOSAL

1-7. GENERAL

Each wastewater disposal system consists of the following: collecting the wastewater, transporting it to a central location, treating the wastewater to render it safe and innocuous, and disposing of the resulting effluent. Figure 1-1 illustrates a complete wastewater system. For example, wastewater removed may leave a house or dwelling by way of a sewer system. The sewer system structures convey the wastewater to the treatment plant for processing, chlorinating, and disposing of the now treated wastewater through a connecting outfall sewer.

1-8. OBJECTIVE OF WASTEWATER TREATMENT

The objective of wastewater treatment is to remove as many of the residues as possible and bring the wastewater supply as nearly as practicable back to the quality of the original water supply. Although potable water is never produced at the treatment plant, the wastewater treatment processes at one town or installation are often the first steps of water treatment for those farther down a stream. In any instance, wastewater treatment plant processing should be carried sufficiently far to ensure that no nuisance condition or health hazard will result by the final disposal of the effluent and that the quality of the water in receiving streams is not seriously impaired. In addition, the effluent must meet applicable Federal, state, and local discharge criteria.

1-9. WASTEWATER COLLECTION SYSTEMS

The water collection system transports wastewater from its origin to a designated destination. The purpose of a wastewater collection system is to safeguard the soldiers from disease-causing organisms, industrial wastes and so forth, as the wastewater is removed from its point of origin to the point for treatment or disposal (discussed in following lessons). Sanitary collection systems which use conveying structures and pumps are designed to remove these domestic and industrial wastes. Interceptors and traps are used as preventive maintenance measures prior to the wastewater entering the collection system. Surface drainage is excluded by rainwater during storms.

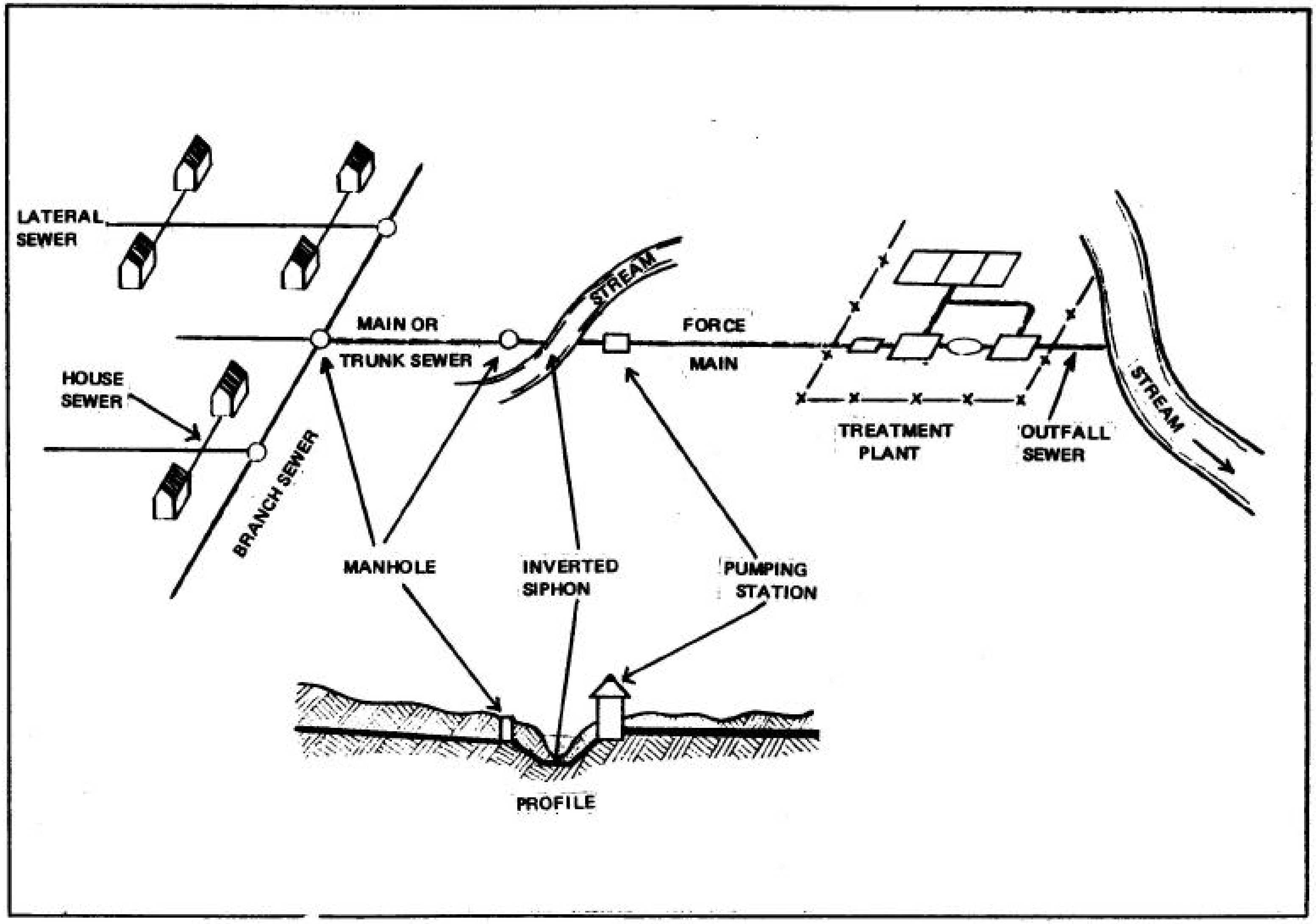


Figure 1-1. Complete wastewater system.

a. **Interceptors and Traps.** Receptacles, which are preventive maintenance interceptors and traps, in dwellings and buildings serve as waste disposal collectors for other than ordinary household wastewater. These specially designed interceptors or traps are frequently required for prompt removal of troublesome wastes before they enter the wastewater collection system.

(1) Grease interceptors and traps. Removing grease from greasy wastes is essential to proper functioning of wastewater systems. Grease is collected in two ways: by ceramic or cast-iron grease interceptors (see Figure. 1-2) installed inside kitchens and other facilities that generate waste grease in comparable or greater quantity, and by concrete or brick grease traps outside the building. Inside grease interceptors are the most common type unit and when properly maintained, they collect about 90 percent of the grease from greasy wastes. Proper maintenance requires daily removal of all solids and washing of all removable baffles, and a complete cleaning weekly.

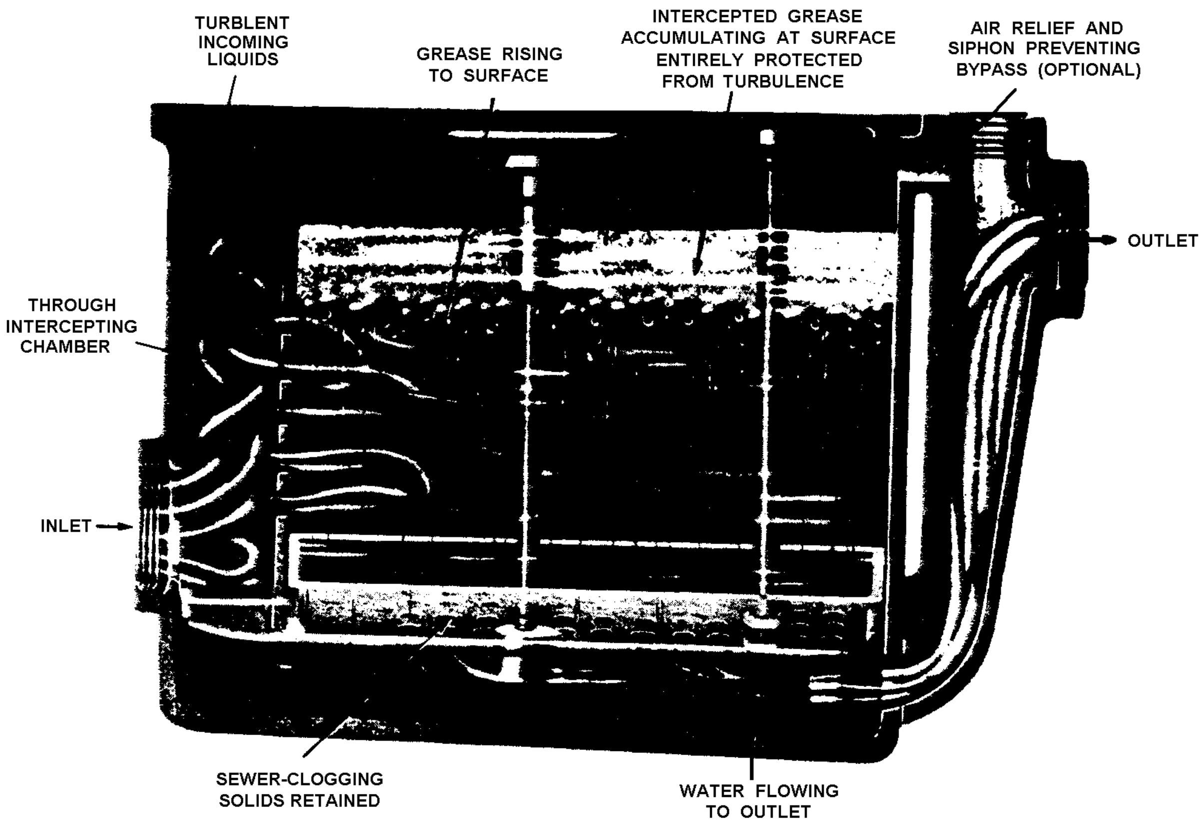


Figure 1-2. A grease interceptor (or inside grease trap).

(2) Hair traps. Hair traps are installed as waste connections or collections in lavatories. These traps are manufactured with baffled partitions and screens to keep hair, lint, and other material out of waste lines. Traps must be cleaned frequently to ensure satisfactory service.

(3) Plaster traps. Plaster traps are installed in waste connections to sinks in hospitals, laboratories, industrial plants, and other places where plaster of paris and other insoluble materials are used. These traps keep foreign material from waste lines. Material accumulating in the traps must be removed frequently to ensure satisfactory service.

(4) Gasoline and oil interceptors. Discharging gasoline, kerosene, or any other volatile liquid into sewers is strictly prohibited. Volatile liquids accumulating in sewers may cause explosions and destroy sewer lines or the treatment plant. They also interfere with proper operation of the plant. Signs of gasoline, lubricating oils, or grease in sewers must be traced to their source. To remove this explosion hazard from the wastewater collection system, gasoline and oil interceptors built on the same principle as grease interceptors are installed in drains from garages, washracks, and shops where greasy wastes are discharged in manageable amounts. The gasoline, oil, and grease accumulating in the interceptor must be skimmed off at regular intervals to assure effective removal of the hazard.

b. **Structures.** A wastewater collection system consists of a collection or group of sewer pipes, pumps, and other structures, as necessary, to transport or convey wastewater for treatment and final disposal. These structures include:

(1) Plumbing fixtures. These fixtures consist of sinks, flush toilets, shower drains, and the like through which waste enters the collecting system. A P-trap (see Figure 1-3) is important in the construction or installation of a plumbing fixture. Weak wastewater remaining in the P-trap acts as a water seal between the fixture and the remainder of the collection system. Accordingly, odors and toxic gases from the sewer do not escape through the fixture but escape instead through the vent in the house sewer.

(2) House sewer. A pipe or pipes connecting the sanitary plumbing facilities of a single building to a common sewer. A vent pipe which permits wastewater to flow without siphoning the water seal in the P-traps is included as a part of the house sewer.

(3) Lateral sewer. A sewer line connecting to a branch or other sewer and having no other common sewer tributary to it.

(4) Branch sewer. A sewer that is serving a relatively small geographic area. Any sewer serving more than one house is termed a *common sewer*.

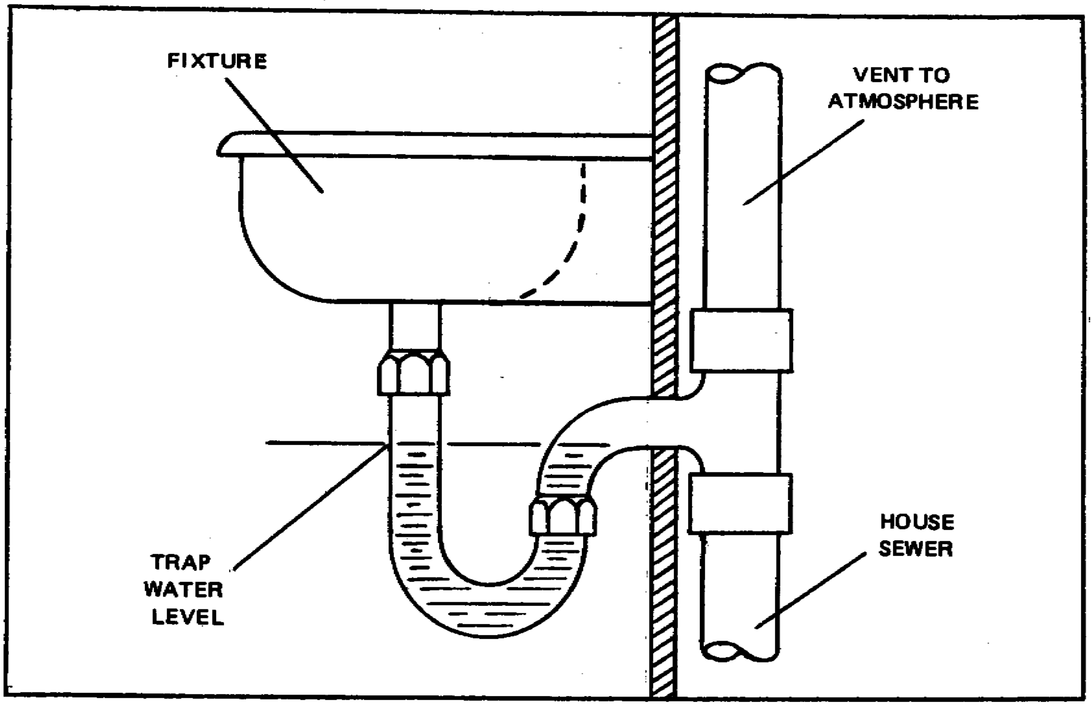


Figure 1-3. P-trap for sanitary plumbing fixture.

(5) Main sewer. A sewer line to which two or more branches are connected

(6) Trunk sewer. A sewer with many branches which provides the outlet for a large geographic area.

(7) Force main. A sewer main carrying wastewater under pressure from a pumping station.

(8) Inverted siphon (depressed sewer). A portion of a sewer line that is placed deliberately below the drainage grade of the rest of the line such that the depressed portion is filled with wastewater at all times. It is especially useful for filling pumps at a pumping station.

(9) Manhole. A manhole is used to enter the sewer system to inspect and to clean the line. Whenever the sewer pipe changes direction, a manhole is required, 300 to 400 feet apart. For large mains of 60 inches, manholes are often spaced from 300 to 600 feet apart.

(10) Pumping station. A place for pumps and other equipment which lifts wastewater to a higher elevation.

(11) Outfall sewer. A sewer line leading from a collecting system (or from a treatment plant) to the final disposal point.

c. **Principles of Design.**

(1) Lateral sewers, branch sewers, and usually, main sewers are laid to permit gravity flow of their contents (see Figure 1-4). Usually the slope is such that the wastewater flow rate is 2 feet per second or more when the line is half full or full. This is known as the "scouring velocity," below which solid material would tend to settle out in the line. Sewer pipes are of sufficient size to carry a peak flow of about 3.7 times the average flow expected from the area served. For gravity flow lines, sewer pipe of vitrified tile; concrete; cement-asbestos; or bituminous-impregnated fiber may be used. For force mains and stream crossings, cast-iron or cement-asbestos pipe is used. Caulking of suitable material is used in the joints.

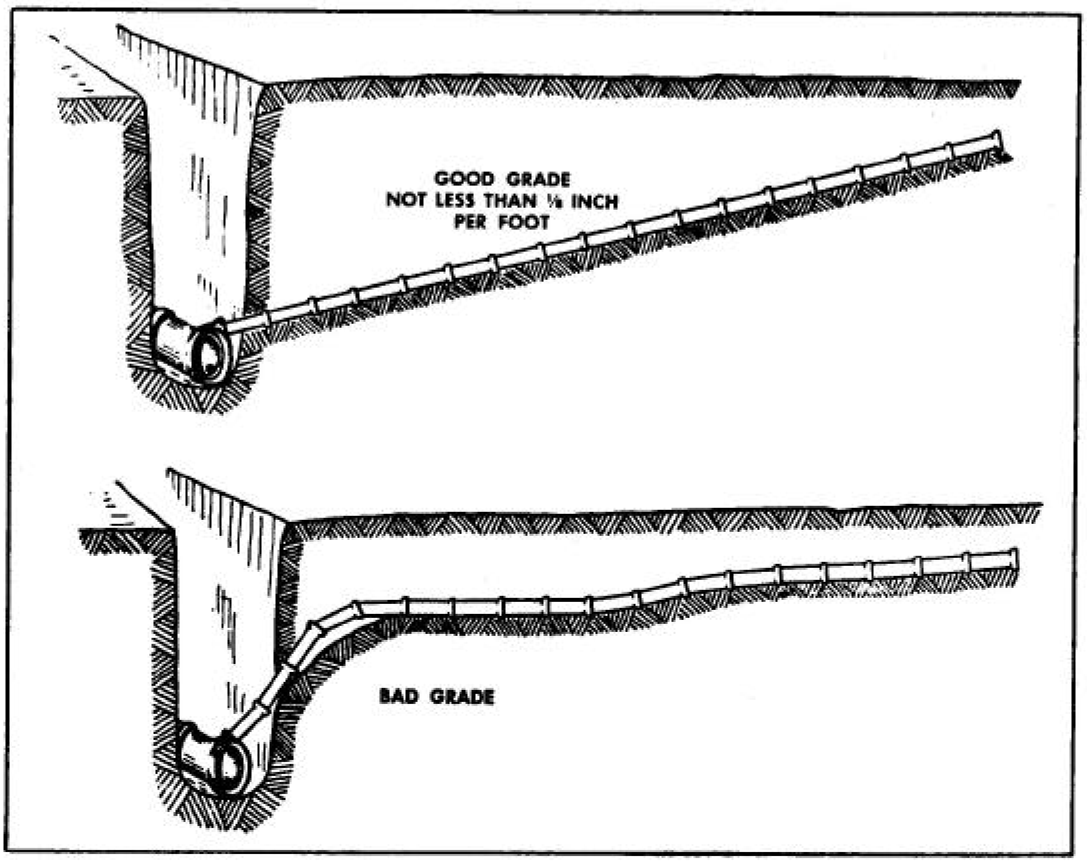


Figure 1-4. Good and bad grades for sewer lines.

(2) To the maximum extent practicable, sewers are laid in straight lines (see Figures 1-4, 1-5). Corners and sharp bends slow the flow rate, permit clogging, and make line cleaning difficult. Manholes (see Figure 1-6) are located at each change of slope of a branch or larger sewer and generally are placed at the end of each lateral. Where sewers connect, a Y-channel is formed in the base of the manhole.

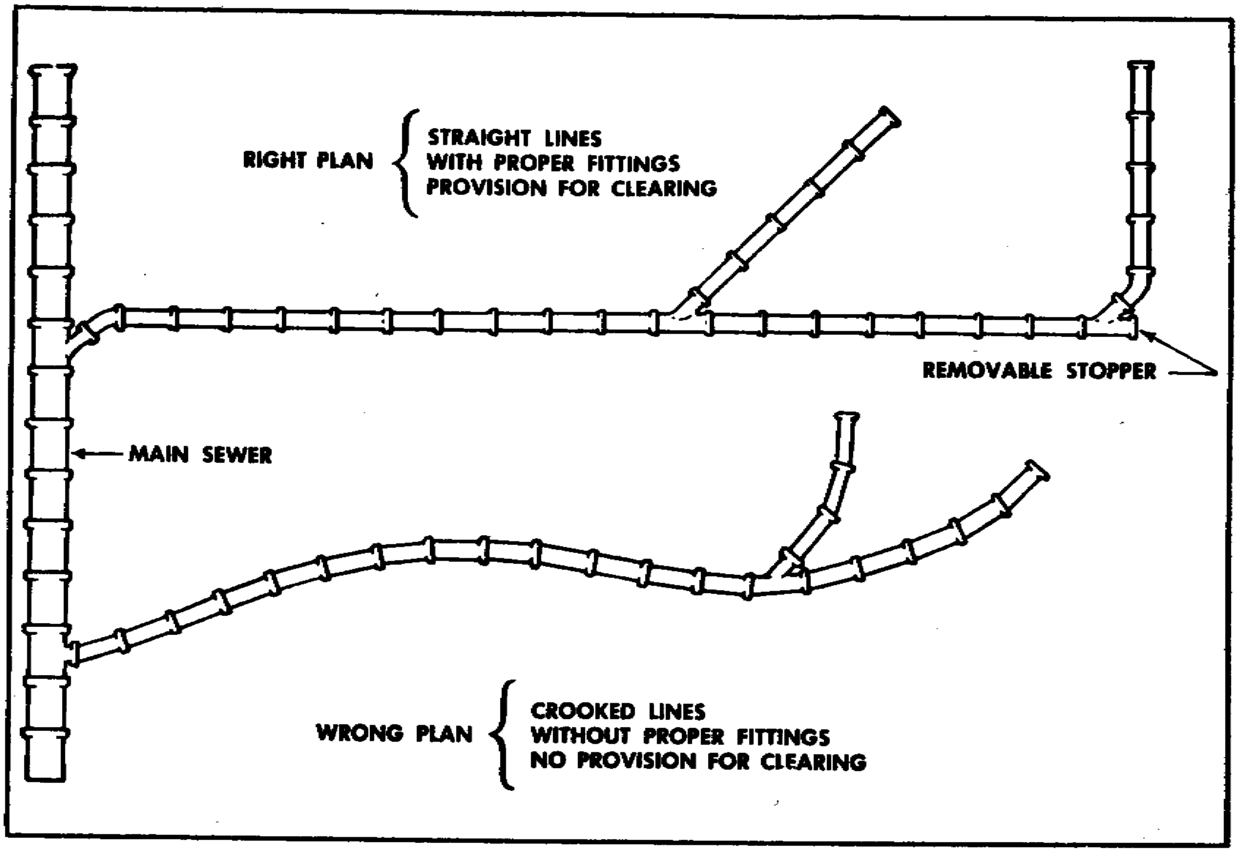


Figure 1-5. Good and bad plans for sewer lines.

(3) Care must be exercised in the installation of a wastewater collection system to prevent the occurrence of indirect cross connections.

(a) Indirect cross connections can occur when sewer lines and potable-water lines are laid underground in the same trench. The cross connection occurs when the water line breaks and admits wastewater that has escaped through loose joints or breaks in the sewer lines. Avoid laying these lines in the same trench. The water piping is to be enclosed in a separate trench above the sewer line.

(b) Indirect cross connections can also occur when sewer and water lines are laid separately but nearby especially in acid soils or land areas made from cinders. A method for avoiding such cross connections is shown in Figure 1-7.

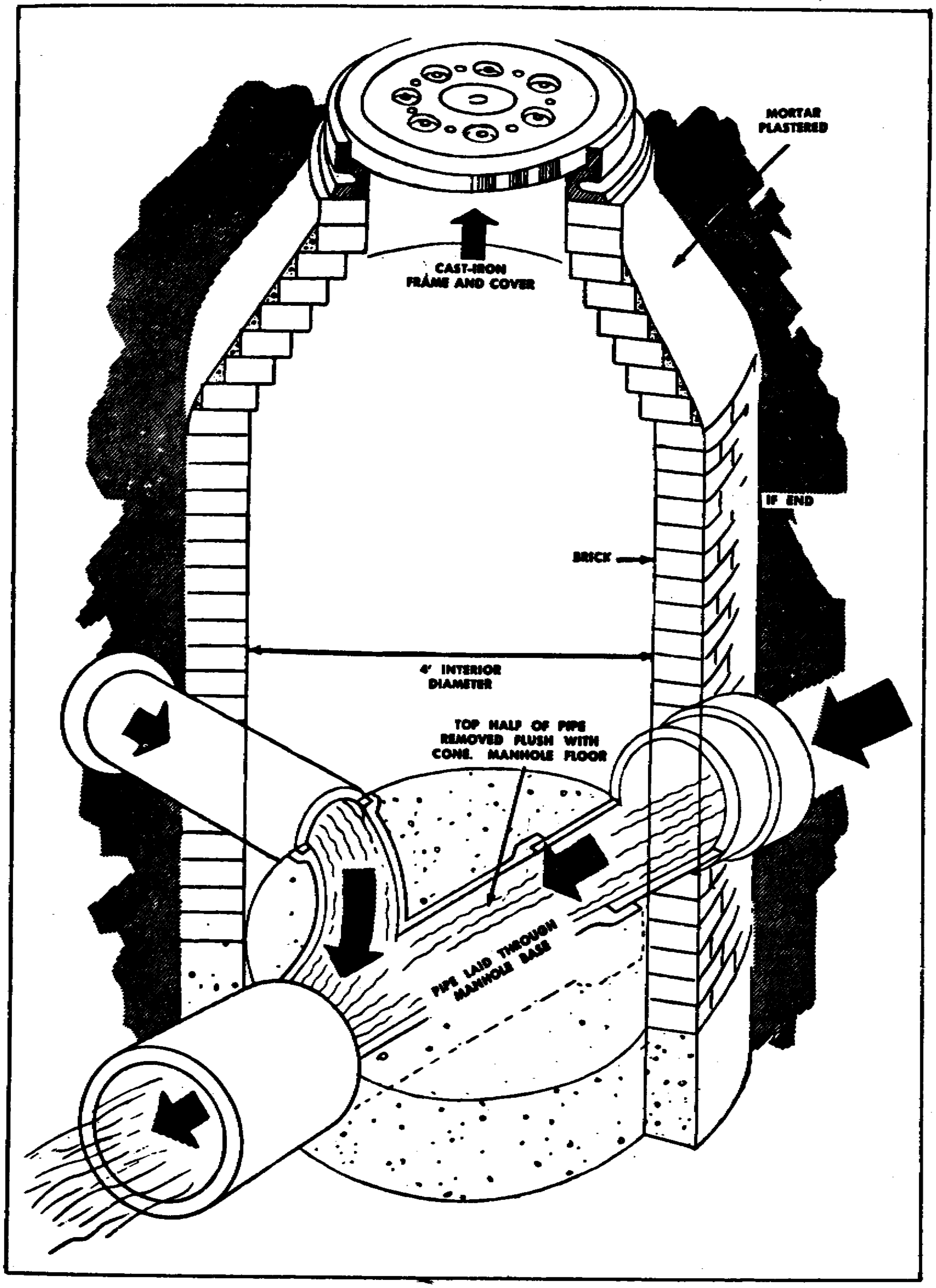


Figure 1-6. Manhole.

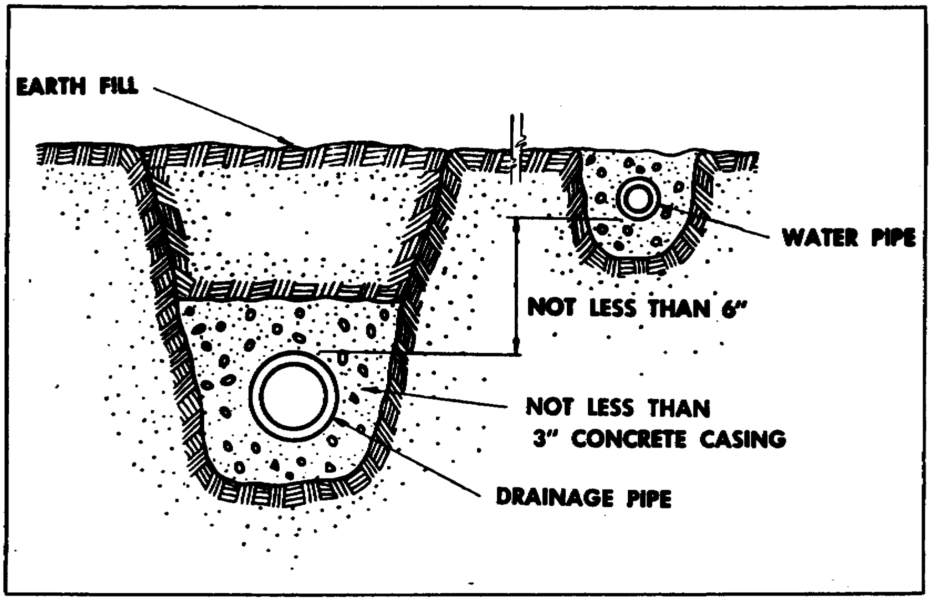


Figure 1-7. Prevention of cross connection in acid or cinder fill.

d. **Pumping.**

(1) Requirement. Pumping is necessary if the slope of the wastewater line does not produce required minimum velocity or where wastewater must be lifted to a higher elevation. Wastewater can be pumped through pressure lines (force mains) regardless of their slope, or it can be raised high enough at pumping stations so that gravity provides the required velocity.

(2) Operation. Nonclogging centrifugal wastewater pumps are most satisfactory for pumping wastewater. Pumps are usually set in pairs to give 100 percent standby service during maximum flow. When the wastewater in a sump reaches a predetermined depth, a float switch starts a pump. When the sump is almost empty, an automatic switch stops the pump. The starting-switch control of the standby pump is set to start at a slightly higher water level than the first pump and to stop at the same low-water level. Starting switches are set so that pumps operate alternately, or the switch mechanism is changed at frequent intervals so that each pump operates about the same length of time. Pump motors are located so they will not become flooded if they fail to function or a shutoff valve is provided to stop the flow when the water level endangers the drive unit. Pump stations may be entirely manually controlled.

(3) Maintenance. Proper maintenance assures efficient operation and avoids breakdowns. Breakdowns may cause health hazards by backing up wastewater in buildings or flooding low areas. Odors from lack of cleanliness in pumping stations located in housing areas are especially objectionable. Improper ventilation of the pump house will allow accumulation of acid-laden condensate from wastewater that severely

corrodes concrete, masonry, and steelwork. Infrequent or insufficient cleansing of wastewater containers permits the accumulation of gas and explosive vapors. Thus, while the pumping station may be of the automatic type, it still requires daily attention.

1-10. WASTEWATER TREATMENT

There are basically three types of stages or processes that take place to render wastewater for disposal. These processes are called primary, secondary, and tertiary treatment. Likewise, there are three types of treatment plants -- primary, secondary, and tertiary -- that reduce the pollutant load in wastewater and chlorinate it before discharging the effluent into outfall sewer.

a. **Primary Treatment.** Primary treatment, essentially a physical process, includes the removal of settleable and floating residues. The process order is screening, followed by grinding or shredding if the facility or equipment is present (in this subcourse, we will assume that it is), and then grit removal, primary clarification of sedimentation, and sludge removal.

(1) Screening and/or grinding. Screening and grinding prevent the entrance into the treatment plant of large objects such as rags, pieces of wood, dead animals, and other objects which may clog pipes, pumps, or other mechanical equipment. Types of equipment most commonly used are fixed-bar screens and communitors.

(a) Fixed-bar screens -- a series of evenly spaced bars set in the wastewater flow.

(b) Communitors -- machines for cutting or shredding solids and passing them to the wastewater flow.

(2) Grit removal. Grit removal is the preliminary removal of nonfiltrable, inorganic material (sand, gravel, cinders, etc.). This material, if not removed, will damage pumps and other equipment. It will also settle in digesters (see para 1-10b(4)), thus reducing their capacity and treatment efficiency and necessitating frequent and costly cleaning. Grit removal is accomplished by passing wastewater through a grit chamber that retards the flow enough to permit the grit to settle. There are two types of grit removal units commonly used -- the flow rate controlled grit removal unit and the aerated grit removal unit. These units are discussed in lesson 2.

(3) Sedimentation. When fresh domestic wastewater stands quiescent or flows very slowly, a considerable portion of the nonfiltrable residue will settle fairly rapidly. Under average conditions, most of the settling occurs within 1 hour. The quantity and rate of sedimentation that occurs after 2 hours is almost negligible. Sedimentation may be accomplished in any of the following devices.

(a) Septic tank. A septic tank is a device that receives raw wastewater from a single residence, several residences, a hotel, or an institution. The septic tank retains the wastewater long enough for the settleable residue to accumulate on the bottom. The effluent is discharged through an overflow pipe.

(b) Imhoff tank. An Imhoff tank is a two-story tank that serves a small installation or community. It is a further refinement of the septic tank principle whereby the wastewater enters the upper chamber and, as it passes slowly through, solids settle to the lower chamber. A detention period of 2 to 3 hours in an Imhoff tank will reduce nonfiltrable residue by 45 to 60 percent. Two types of Imhoff tanks are shown in Figures 2-11 and 2-12 of lesson 2.

(c) Separate settling tank. The separate settling tank is the most common device used for primary settling at large installations and municipal wastewater systems. It may be circular or rectangular, having a sloped hopper bottom for the accumulation of solids. A 2-hour sedimentation period will usually effect removal of 50 to 60 percent of the suspended matter and 30 to 40 percent of the BOD (see para 1-5b(2)). With the addition of chemicals to effect coagulation, as in water treatment, sedimentation may remove as much as 75 to 85 percent of the suspended matter and 50 to 70 percent of the total BOD.

(4) Sludge removal. Removal of sludge is required to ensure continued efficient operation of primary treatment equipment. Sludge from septic tanks is normally pumped into commercially operated tank trucks and disposed of by burial or discharge into municipal wastewater systems. Sludge from the bottom compartments of Imhoff tanks is pumped on a periodic basis, as digestion is completed, into sludge drying beds, tank sludge lagoons, or some similar type of disposal facility. Sludge from primary settling tanks is removed continuously, or frequently, to prevent septic conditions from developing in the tank. It is pumped into sludge digesters for complete digestion (see para 1-10b(4)).

b. **Secondary Treatment.** The secondary wastewater treatment plant performs, essentially, a biochemical process, although some of the same physical processes employed in primary treatment are also involved. Wastewater that received only primary treatment usually still contains 50 to 60 percent of the original wastewater material, including all of the dissolved matter, most of the colloidal and finely divided organic matter, and approximately as high a bacterial content as the raw wastewater. This partly treated wastewater is highly putrescible and will pollute large bodies of receiving water unless further treated. The objectives of secondary treatment are to bring about a rapid oxidation and stabilization of this remaining organic matter, to remove the resulting settleable solids, and to reduce the bacterial content. The following processes are considered secondary treatment processes.

(1) Filtration. Filtration effects biological oxidation of organic material on and in beds of stone or sand.

(a) Absorption trenches (subsurface tile fields). These trenches are perforated tile lines laid in gravel beds in loose, porous soil into which the effluent from a septic tank is continuously or intermittently dosed. Oxidation takes place as the effluent percolates through the gravel and soil.

(b) Intermittent sand filters. These are beds of underdrained sand on which settled wastewater is applied. Oxidation takes place in the bed.

(c) Trickling filters. These filters are beds of stone where effluent from primary treatment is intermittently or continuously distributed. Films of organisms that form on the surfaces of the stones stabilize the solids by aerobic methods.

(2) <u>Aeration</u>.

(a) Activated sludge process. This process accelerates aeration whereby the effluent from primary settling is mixed with return sludge and agitated continuously in the presence of oxygen. The activated sludge thus formed has the property of absorbing dissolved organic material and converting it into stable substances that will settle.

(b) Oxidation pond. The pond is a relatively large, shallow pond, either natural or artificial, into which settled wastewater is discharged for natural purification under the influence of sunlight and air.

(3) <u>Secondary settling</u>. Sedimentation is an essential step following biochemical processes such as the trickling filter and the activated sludge process. These biochemical processes *do not* remove organic material; they convert it to a stable form which will settle out by sedimentation. The sludge from final settling tanks is pumped into digestion tanks. In the activated sludge process, a portion is returned and mixed with the settled wastewater entering the aeration tanks.

(4) <u>Sludge digestion</u>. The sludge which settles out during primary and secondary sedimentation is about 95 percent water. The remaining 5 percent is highly putrescible organic matter. It is normally pumped directly into covered tanks and permitted to digest by anaerobic bacterial action. In the Imhoff tank and the septic tank, the sludge settles to the bottom where it is digested anaerobically. Digested sludge is withdrawn and discharged into sludge drying beds. These beds are usually provided with underdrains to facilitate drying. Dried, well-digested sludge is quite stable and is an excellent low-grade fertilizer.

c. **Tertiary Treatment.** A tertiary wastewater treatment plant performs those processes that remove contaminants from wastewater that were not removed by conventional primary and secondary wastewater treatment. The purpose of tertiary treatment is to upgrade the effluent from conventional treatment processes and to renovate wastewater to a level at which it can be reused directly. Very few wastewater treatment plants in operation today employ tertiary treatment methods; however, the

Federal Government has placed increased emphasis on these processes and they will be commonplace, or even mandatory, in the near future. Tertiary wastewater treatment (also referred to as advanced wastewater treatment) may include, but is not limited to, any or all of the following processes.

(1) Carbon absorption. Activated carbon particles are contacted with a flow of wastewater. Dissolved organics are removed from the liquid by adsorption (clinging) to the surface of the carbon particles. Depending on the method, particulate matter may also be removed.

(2) Coagulation-sedimentation. A colloidal suspension consists of particles separated by a dispersing medium. In wastewater, this medium is usually water. Colloid particles can be removed by coagulation. Coagulation is the process of forming gelatinous particles by reducing the repulsive forces between colloids as a result of adding a coagulant. The resulting coagulated groups can be separated from water by sedimentation.

(3) Chemical oxidation. Oxidation by the use of such chemicals as ozone, hydrogen peroxide, and other chemically unstable substances is used to remove dissolved organics, phosphates, and nitrogen compounds. By removing unit electrical charges from these other elements, oxidating agents can alter their physical and chemical properties so as to cause their removal from the water.

(4) Membrane processes.

(a) Electrodialysis. Electrodialysis is a means of removing certain elements from a liquid such as water by electromagnetically forcing the elements through a semipermeable membrane. This method is based on the fact that all charged particles in the solution may be attracted, but only particles of a certain kind may actually physically cross the membrane.

(b) Reverse osmosis. Two solutions of differing strengths are placed in proximity to one another and separated by a water-permeable membrane. Applying pressure to the chamber containing the stronger solution causes a flow of water from the stronger solution to the weaker solution.

(5) Ion exchange. Water containing charged particles can be passed through a filter containing molecules composed of charge ions. As the water passes through the filter, charged ions in the water will selectively exchange position with ions in the filter molecules. Thus, certain ions can be removed from a fluid and replaced by other more desirable ions.

(6) Chlorination. The combined primary and secondary wastewater treatment processes remove or stabilize most of the organic matter present and reduce the bacterial content by 50 percent or more. There is no assurance, however, that the number of pathogenic organisms has been reduced to a satisfactory level unless some

disinfection process is applied. Therefore, chlorination is frequently applied to a treatment plant effluent just prior to its disposal into a receiving stream. Properly controlled chlorination of a wastewater plant effluent will effect a 99.5 percent reduction in total bacterial content.

(7) Disposal. The final effluent from a wastewater treatment plant is normally discharged into a body of water such as an ocean, lake, or stream. This discharged effluent must not create a nuisance; it must not exert harmful effects on the receiving stream or land; and it must meet Federal, state, and local criteria for effluents (see para 1-8).

1-11. SUMMARY

a. Primary wastewater treatment includes:

(1) Screening.

(2) Grinding (includes shredding).

(3) Grit removal.

(4) Sedimentation.

(5) Sludge removal.

b. Secondary wastewater treatment includes:

(1) Aerobic biochemical processes:

(a) Filtration.

(b) Aeration.

(2) Anaerobic biochemical processes (sludge digestion).

(3) Secondary settling.

c. Tertiary wastewater treatment may include, but is not limited to, one or more of the following:

(1) Carbon absorption.

(2) Coagulation-sedimentation.

(3) Chemical oxidation.

(4) Membrane processes.

(a) Electrodialysis.

(b) Reverse osmosis.

(5) Ion exchange.

(6) Chlorination.

(7) Disposal.

d. Figure 1-8 shows schematically the principles of secondary wastewater treatment.

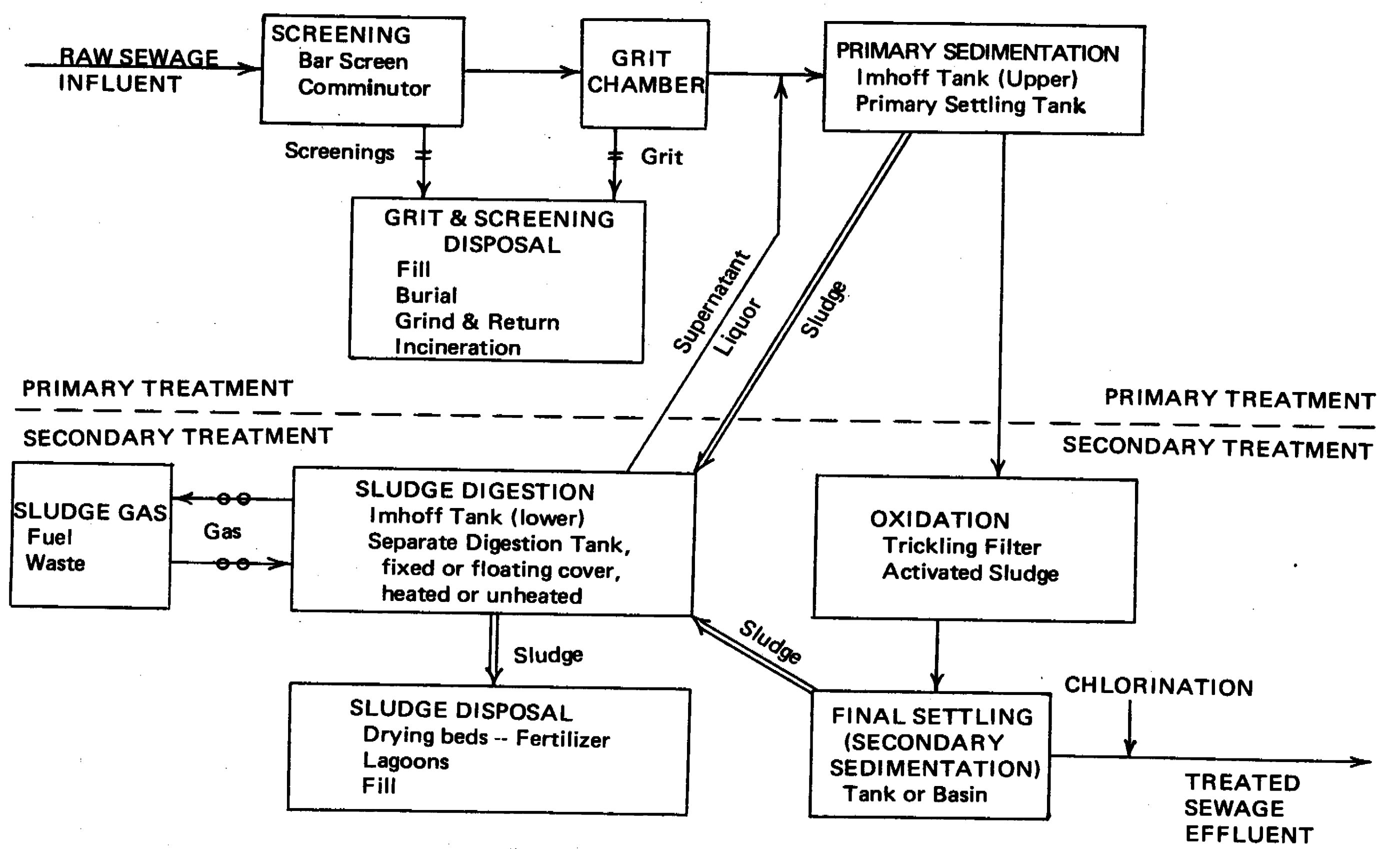


Figure 1-8. Flow diagram-showing principles of secondary wastewater treatment.

Section III. SEPTIC TANK PRACTICE

1-12. GENERAL

a. **Reasons for Septic Tanks.** Wastewater treatment presents special problems for very small installations or small, isolated units. It is not always economically feasible to install separate wastewater treatment facilities for such installations and units. Whenever possible, a small installation should make arrangements to discharge its wastewater into an adequate public or community system. When no such system is available, where soil and site conditions are favorable, and where it is not prohibited by local and/or state ordinances, a properly constructed and installed septic tank system can be expected to give satisfactory results.

b. **Septic Tank Systems.** The basic principle of a septic tank system (see Figure 1-9) follows. The liquid contents of the house sewer (A) are discharged into the septic tank (B) where they undergo primary treatment by sedimentation and anaerobic decomposition (secondary treatment) of the sludge that settles out. The treated effluent is discharged into an absorption field (C) where it receives secondary treatment by aerobic bacterial action and is disposed of by percolation through soil. Therefore, before a septic tank system is installed, three important criteria must be met.

(1) It must be determined that the installation of such a system is permitted under all local, state, and Federal ordinances governing the particular locality. This determination may be made by liaison with the local health authorities.

(2) It must be determined that the absorptive capacity of the soil in the locality is sufficient to permit disposal of the effluent without creating a nuisance, such as ponding because of the inability of the soil to absorb the effluent.

(3) It must be determined that the area available for installing the system is sufficient to provide for adequate disposal while maintaining the required distances from underground water sources, buildings, and property lines.

1-13. SUITABILITY OF SOIL

a. **General.** The first step in the design of a septic tank system is to determine whether the soil is suitable for the absorption of septic tank effluent and, if so, how much area is required. The soil must have an acceptable percolation rate without interference from ground water or impervious strata below the level of the absorption system. In general, the percolation rate should not exceed 60 minutes per inch of fall in water level (not over 30 minutes for seepage pits (see para 1-17a(2)) and the depth of the maximum seasonal elevation of the ground water table or impervious strata (rock formation, etc.) should be at least 4 feet below the bottom of the absorption trench.

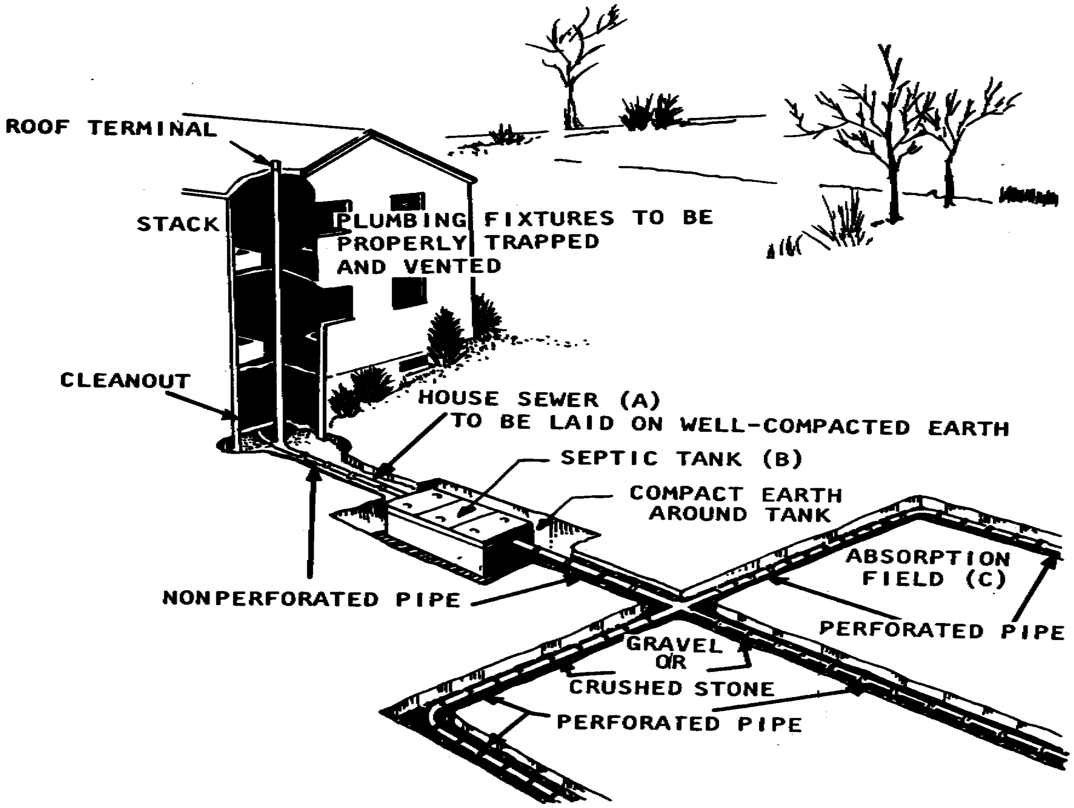


Figure 1-9. Septic tank system.

b. **Percolation Tests.** In the absence of ground water or subsoil information, subsurface sand explorations are necessary to determination the absorptive capacity of the soil and serve as a basis of design for the liquid absorption. A percolation test of the soil at the actual site of where the disposal field will need to be conducted. The information gathered will govern the required area needed for the disposal (absorption) field. The recommended procedure, developed by the Robert A. Taft Sanitary Engineering Center, follows.

(1) Number and location of tests. Six or more tests should be made in separate test holes spaced uniformly over the proposed absorption field site.

(2) Type of test hole. Dig or bore a hole from 4 to 12 inches in diameter, with *vertical* sides, to the depth of the proposed absorption trench. This depth will depend upon several factors such as differences in elevation between the house sewer and the disposal field, necessary grade for connecting lines, and the depth of the pervious soil layer. Some soils have a dense, impervious clay topsoil that must be penetrated to achieve an acceptable percolation rate. Exploratory excavations must determine this condition if a knowledge of the soil conditions does not exist.

(3) Preparation of test hole. Carefully scratch the bottom and sides of the hole with a knife blade or sharp-pointed instrument to remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Remove all loose material from the hole. Add 2 inches of coarse sand or fine gravel to protect the bottom from scouring and sediment.

(4) Saturation and swelling of the soil. It is important to distinguish between saturation and swelling. *Saturation* means that the spaces or separations between soil particles are full of water. This can be accomplished in a short period of time. *Swelling* is caused by intrusion of water into the individual soil particle. This is a slow process, especially in clay type soil, and is the reason for requiring a prolonged soaking period. In the conduct of the test, carefully fill the hole with clear water to a minimum depth of 12 inches over the gravel. In most soils, it is necessary to refill the hole by supplying a surplus reservoir of water, possibly by means of an automatic siphon, to keep water in the hole for at least 4 hours and preferably overnight. Determine the percolation rate 24 hours after water is first added to the hole. This procedure is to ensure that the soil is given ample opportunity to swell and to approach the condition it will be in during the wettest season of the year. Thus, the test will give comparable results in the same soil regardless of whether the test is made in a dry or in a wet season. In sandy soils containing little or no clay, the swelling procedure is not essential and the test may be made as described in paragraph 1-13b(5)(c) after the water from one filling of the hole has completely seeped away.

(5) Percolation-rate measurement. With the exception of sandy soils, percolation-rate measurements are made on the day following the procedure described in paragraph (4), above.

(a) If water remains in the test hole after the overnight swelling period, adjust the depth to approximately 6 inches over the gravel. From a fixed reference point, measure the drop in water level over a 30-minute period. This drop is used to calculate the percolation rate.

(b) If no water remains in the hole after the overnight swelling period, add clear water to bring depth of water in the hole to approximately 6 inches over the gravel. From a fixed reference point, measure the drop in water level at approximately 30-minute intervals for 4 hours, refilling 6 inches over the gravel as necessary. The drop that occurs during the final 30-minute period is used to calculate the percolation rate. The drops during prior periods provide information for possible modification of the procedure to suit local circumstances.

(c) In sandy soils (or other soils in which the first 6 inches of water seeps away in less than 30 minute after the overnight swelling period), the time interval between measurements is 10 minutes and the test is run for one hour. The drop that occurs during the final 10 minutes is used to calculate the percolation rate.

1-14. SOIL ABSORPTION SYSTEM

a. **Location.** When a soil absorption system is determined to be usable, the location of the components must be determined. A safe distance must be maintained between the site and any source of water supply. Since the distance that pollution will travel underground depends upon numerous factors, including the characteristics of the subsoil formations and the quantity of wastewater discharged, no specified distance would be absolutely safe in all localities. Ordinarily, of course, the greater the distance, the greater will be the safety provided. In general, when not in conflict with local ordinances, the location of components of wastewater disposal systems should be as shown in Table 1-2.

Horizontal Distance (feet)					
Component of System	Well or suction	Water supply (pressure)	Stream	Dwelling	Property line
Building sewer	50	10*	50	——	——
Septic tank	50	10	50	5	10
Disposal field	100	25	50	20	5

*Where the water supply line must cross the sewer line, the bottom of the water service within 10 feet of the point of crossing shall be at least 12 inches above the top of the sewer line. The sewer line shall be of cast iron with leaded or mechanical joints at least 10 feet on either side of the crossing.

Table 1-2. Minimum distances between components of wastewater disposal system.

b. **Design.** A soil absorption (disposal) field consists of a field of 12-inch lengths of 4-inch agricultural drain tile, 2- to 3-foot lengths of vitrified clay sewer pipe, or perforated, nonmetallic pipe. The individual laterals preferably should not be over 100 feet long and the trench bottom and tile distribution lines should be level. Use of more and shorter laterals is preferred because most of the field will still be serviceable if something should happen to disturb one line. Many different designs may be used in laying out subsurface disposal fields. The choice may depend on the size and shape of the disposal area, the capacity required, and the topography of the disposal area.

Figure 1-10 illustrates a typical absorption trench layout for level ground. If the slope of the field exceeds about 6 inches in any direction within the area, serial distribution may be used. In serial distribution, individual absorption trenches (laterals) are laid level with the long axis perpendicular to the slope. The laterals are then connected in series as shown in Figure 1-11 so that the upper trench is filled first; then excess liquid is carried by means of a closed line to the next succeeding or lower trench.

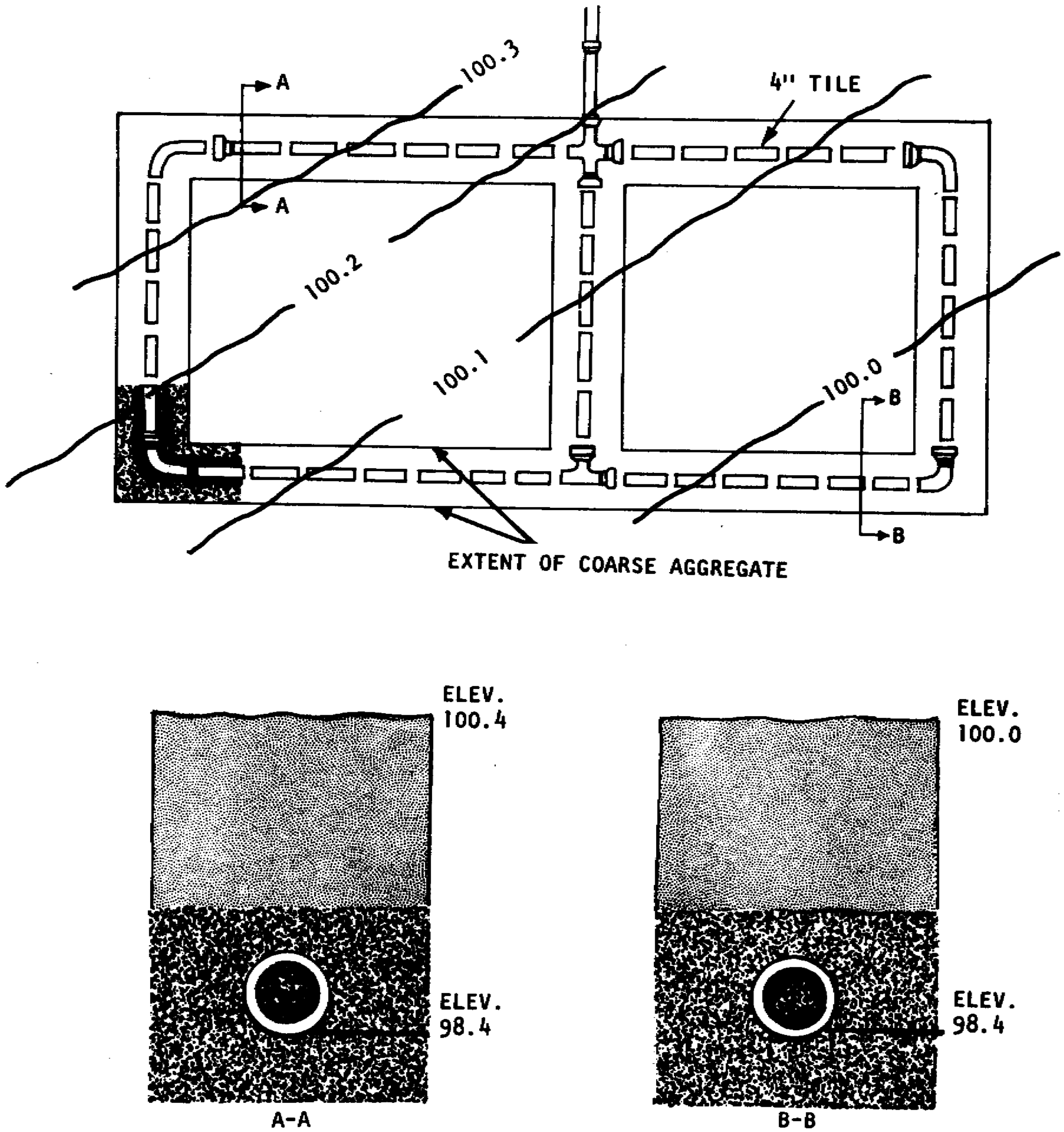


Figure 1-10. Absorption-field system for level ground.

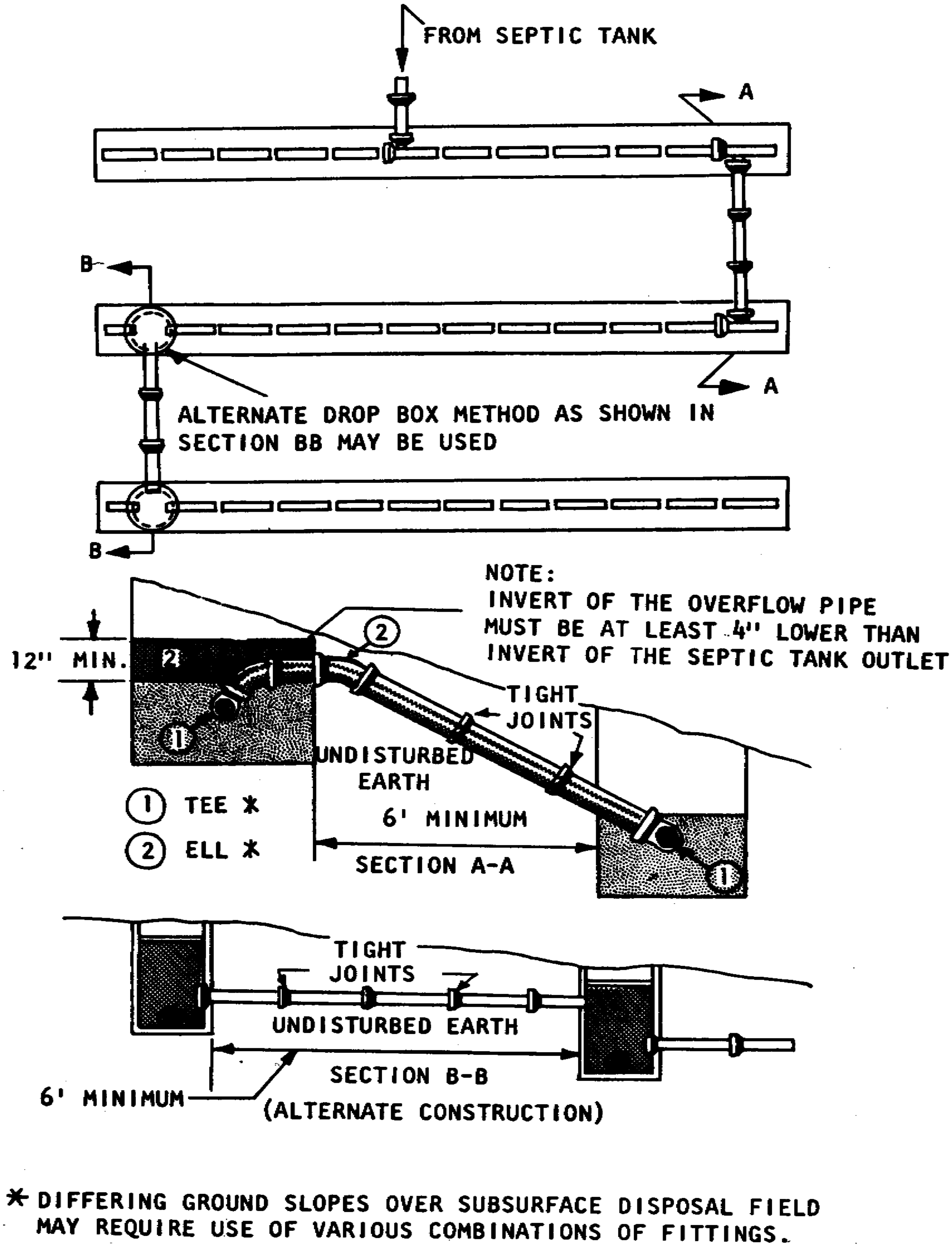
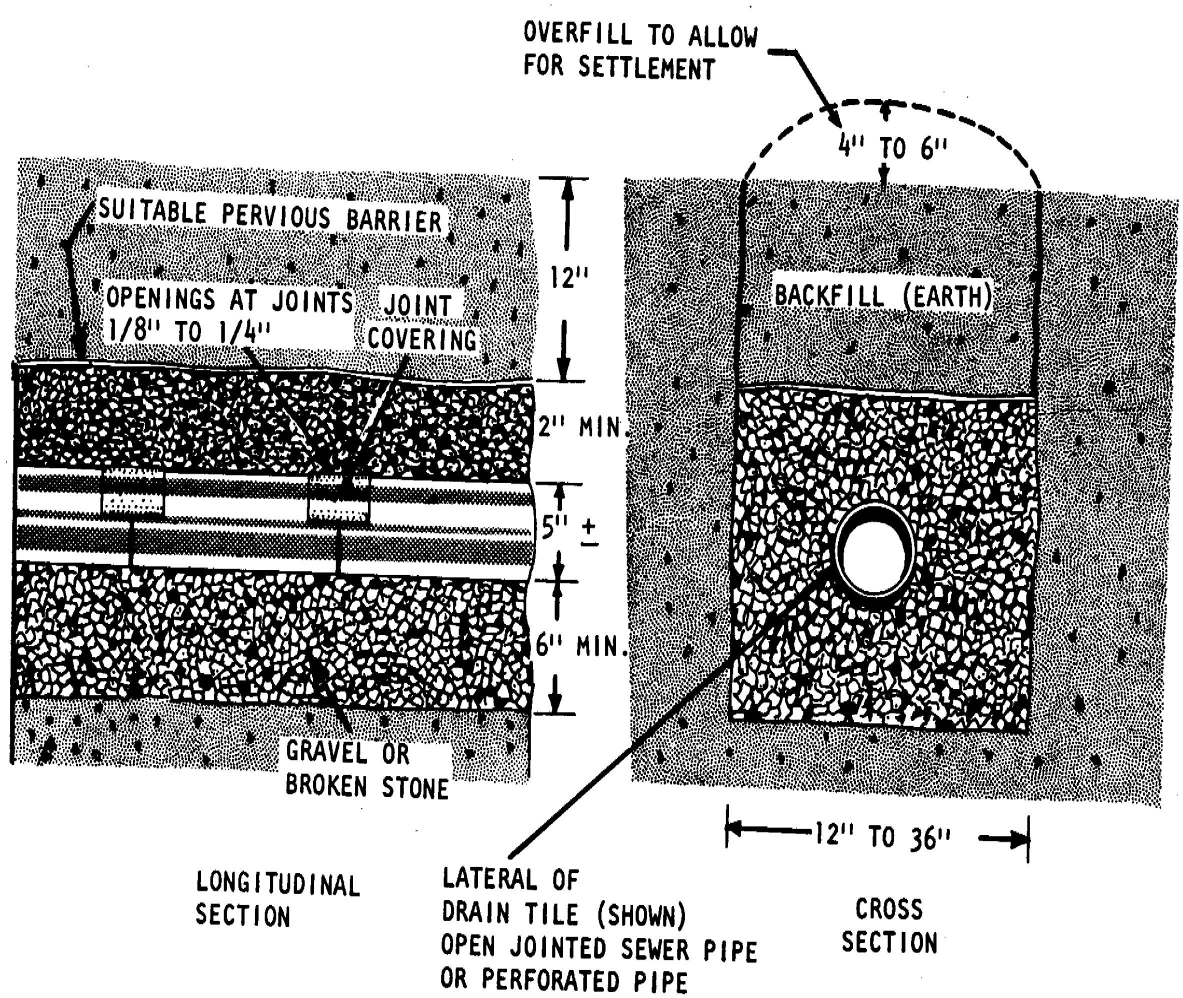


Figure 1-11. A relief line arrangement for serial distribution.

c. **Construction.** Trenches should be from 1 to 3 feet wide and at least 2 feet deep in order to provide the minimum required gravel depth and earth cover. The spacing between laterals is generally governed by practical considerations dependent on the type of construction equipment, safety, and so forth, but the distance between trenches should be at least twice the depth of gravel. For serial distribution on sloping ground, trenches should be separated by at least 6 feet. Clean, graded gravel or rock ranging in size from 1/2 inch to 2 1/2 inches should surround the pipe. The material should extend from at least 2 inches above the top of the pipe to at least 6 inches below the bottom of the pipe. If tile is used, the upper half of the joint openings should be covered as shown in Figure 1-12. The top of the gravel should be covered with untreated building paper or similar pervious material to prevent the gravel from becoming clogged by the earth backfill. The top of a new absorption trench should be hand-tamped and should be overfilled with about 4 to 6 inches of earth to prevent the top of the trench from settling below the surface of the adjacent ground. Once a tile field is constructed, fencing or posting to prevent crushing the tile should exclude all heavy vehicle traffic. Planting shrubs or trees over the field is not good practice since the roots tend to clog the tile lines; however, grass over the line assists in removing the moisture and keeping the soil open. Freezing rarely occurs in a carefully constructed system kept in continuous operation.

d. **Absorption Area.** The required absorption area is dependent upon the results of the soil percolation test and the number of bedrooms served by the system.

(1) Residential requirements. Table 1-3 gives the absorption area requirements for individual residences in square feet of trench bottom per bedroom for percolation rates up to 60 minutes (the minimum acceptable rate for a soil absorption system). The system should be designed to provide for the number of bedrooms that can be reasonably anticipated, including the unfinished space available for conversion as additional bedrooms. It is also desirable to provide sufficient land area for an entire new system if the first one fails. To calculate the required absorption area, enter Table 1-3 at the percolation rate previously determined and find the absorption area per bedroom in square feet. Multiply this figure by the number of bedrooms to find the total absorption area required.



NOTE: DRAIN TILE LAID WITH JOINTS OPENED FROM 1/8 TO 1/4 INCH. SPECIAL COLLARS MAY BE USED IF DESIRED.

Figure 1-12. Absorption trench and lateral.

Percolation (min per inch of fall)	Required absorption area in sq. ft) per bedroom	Percolation rate (min per inch of fall)	Required absorption area in sq. ft. per bedroom
1	70	10	165
2	85	15	190
3	100	30	250
4	115	45*	300
5	125	60*	330

(Provides for garbage grinder and automatic washing machine.)
*Unsuitable for seepage pits if over 30.

Table 1-3. Absorption area requirements for individual residences.

EXAMPLE: A 3-bedroom house on a lot where the precolation rate is 1 inch in 15 minutes requires an absorption area of 190 square feet x 3 = 570 square feet. For trenches 2 feet wide with 6 inches of gravel below the distribution pipe, the required total length of trench would be 570 ÷ 2, or 285 feet. If this were divided into 5 equal portions (that is, 5 laterals), the length of each line would be 285 ÷ 5, or 57 feet. If the laterals are placed 6 feet apart, the width of the field will be 5 (laterals) x 2 (feet wide) = 10 feet, plus 4 (spaces between laterals) x 6 (feet) = 24 feet, or 34 feet. Thus the size of the disposal field must be 34 feet wide x 57 feet long = 1,983 square feet, plus additional land required to maintain minimum distances from wells, property lines, etc.

(2) Institutional requirements. Soil absorption area requirements for institutions, business establishments, multiple-family residences, and recreation areas vary widely. Quantities of wastewater flows vary from 60 gallons per person per day in apartment houses to over 250 gallons per person per day in hospitals. In designing a soil absorption system for institutional use (which would include a small military unit), the best available data should be used to estimate the average wastewater flow. Once the flow is determined, the soil absorption area may be determined by dividing the daily flow by the maximum rate of wastewater application found in Table 1-4. Table 1-4 does not include an allowance for garbage grinders and automatic washing machines. If these applications are used, the required trench area should be increased 20 percent and 40 percent, respectively.

Percolation (min per inch of fall) per day	Maximum rate of wastewater application (gal per sq. ft)	Percolation rate (min per inch of fall) per day	Maximum rate of wastewater application (gal per sq. ft.)
1	5.0	10	1.6
2	3.5	15	1.3
3	2.9	30	0.9
4	2.5	45*	0.8
5	2.2	60*	0.6

(Garbage grinders and automatic washing machines not included.)
*Unsuitable for seepage pits if over 30.

Table 1-4. Allowable rate of wastewater application to a soil absorption system.

EXAMPLE: A small military installation has a daily wastewater flow of 5,000 gallons. The percolation rate is 5 minutes per inch. From table 1-4, the maximum wastewater application rate is 2.2 gallons per square foot per day. Then 5,000 ÷2.2 = 2,270 square feet of absorption area required. If trenches 2 feet wide are used, 2,270 ÷2 or 1,135 linear feet of absorption trenches are required.

If garbage grinders are used, the requirement must be increased by 20 percent:

1,135 + .20(1,135) = 1,362 linear feet.

If automatic washing machines are used, the requirement must be increased by 40 percent:

1.,135 + .40(1,135) = 1,589 linear feet.

If both garbage grinders and automatic washing machines are used, the requirement must be increased by 60 percent:

1,135 + .60(1,135) = 1,816 linear feet.

1-15. SEPTIC TANKS

a. **Function.** Untreated liquid household wastes will quickly clog all but the most porous gravel formations. A septic tank conditions wastewater so that it may be more readily percolated into the subsoil of the ground. Thus, the most important function of a septic tank is to provide protection for the absorptive ability of the subsoil.

(1) Clogging of soil with tank effluent varies directly with the amount of nonfiltrable residue in the liquids. As wastewater from a building enters a septic tank, its

rate of flow is reduced where larger solids can sink to the bottom or rise to the surface. These solids are retained in the tank and the clarified effluent is discharged.

(2) A septic tank combines two processes. Sedimentation takes place in one portion of the tank and the accumulated solids are digested by anaerobic decomposition in the lower portion. This decomposition or treatment of wastewater under anaerobic conditions is termed "septic," hence the name of the tank. The heavier residues settle to the bottom of the tank forming a blanket of sludge. The lighter solids, including fats and greases, rise to the surface and form a layer of scum. A considerable portion of the sludge and scum are liquefied through decomposition or digestion. During this process, gas is liberated from sludge. This gas carries portions of the solids to the surface where they accumulate with the scum. Ordinarily, they undergo further digestion in the scum layer and parts settle again to the sludge blanket on the bottom. This action is retarded if there is much grease in the scum layer. The settling is also retarded because of gasification in the sludge blanket. Furthermore, there are relatively wider fluctuations of flow in small tanks than in large units. This effect has been recognized in Table 1-5, which shows the recommended minimum liquid capacities for household tanks.

Number of Bedrooms	Recommended minimum tank capacity	Equivalent capacity per bedroom
2 or less	750	375
3	900	300
4	1,000	250
Each additional, add 250	----	250

(Provides for use of garbage grinders, automatic clothes washers, and other household appliances.)

Table 1-5. Liquid capacity of tanks (gallons).

(3) Septic tanks do not accomplish a high degree of bacterial removal. Although the wastewater undergoes treatment in passing through the tank, this does not mean that the infectious agents will be removed. This means that septic-tank effluent cannot be considered safe. The liquid that is discharged from the tank is, in some respects, more objectionable than that which goes in; it is septic and malodorous. This, however, does not detract from the value of the tank. Its primary purpose is to condition the wastewater so that it will cause less clogging of the disposal fields (absorption fields). Further treatment of the effluent, including the removal of pathogens, is effected by percolation through the soil. Disease-producing bacteria will, in time, die out in the unfavorable environment afforded by soil. In addition, certain physical forces during

filtration also remove bacteria. This combination of factors results in the eventual purification of the wastewater effluent.

b. **Location.** Septic tanks must be located where they cannot cause contamination of any well, spring, or other source of water supply. Underground contamination may travel in any direction and for considerable distances unless filtered effectively. Underground pollution usually moves in the same general direction as the normal movement of the ground water in the locality. For this reason, septic tanks should be located downhill from wells or springs. Wastewater from disposal systems occasionally contaminates wells having higher surface elevations; therefore, it is also necessary to rely on horizontal as well as vertical distances for protection. Tanks should never be closer than 50 feet to any source of water supply; greater distances are preferred where possible. The septic tank should not be located within 5 feet of any building. It should not be located in swampy areas or in areas subjected to flooding. In general, the tank should be located where the largest possible area will be available for the disposal field. Consideration should also be given to the location from the standpoint of cleaning and maintenance.

c. **Capacity.** Capacity is one of the most important considerations in septic tank design. Liberal tank capacity is not only important from a functional standpoint, but is also good economy. The required tank capacity is based upon the number of bedrooms for individual residences (see Table 1-5) and upon the daily wastewater flow for institutions (see Figure 1-13).

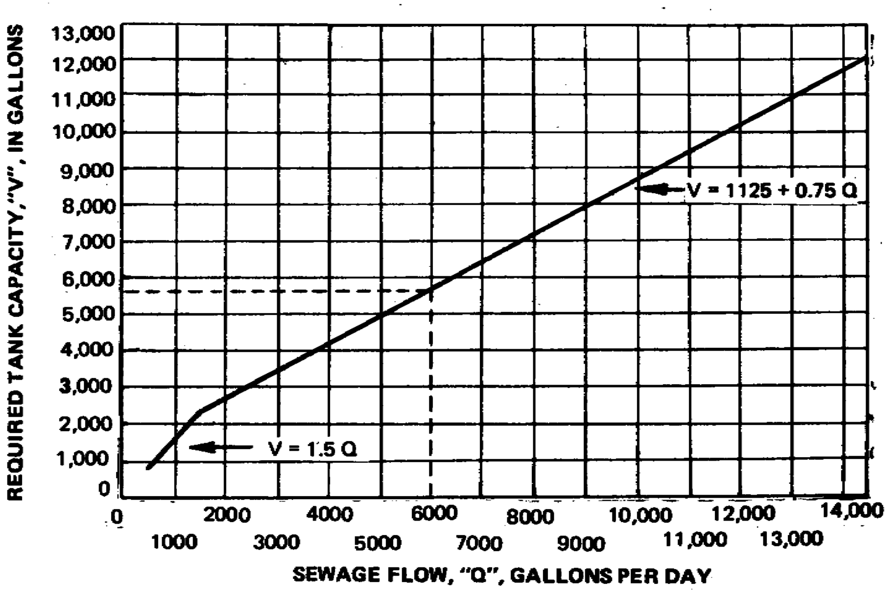


Figure 1-13. Septic tank capacities for wastewater flows up to 14,500 gallons per day.

d. **Design.** Septic tanks may be of many designs. They may be either rectangular or cylindrical. They must be watertight and should be constructed of materials such as concrete, coated metal or vitrified clay, which are not subject to corrosion or decay. A single compartment tank (see Figure 1-14) will give acceptable performance. The available research data indicate, however, that a two-compartment

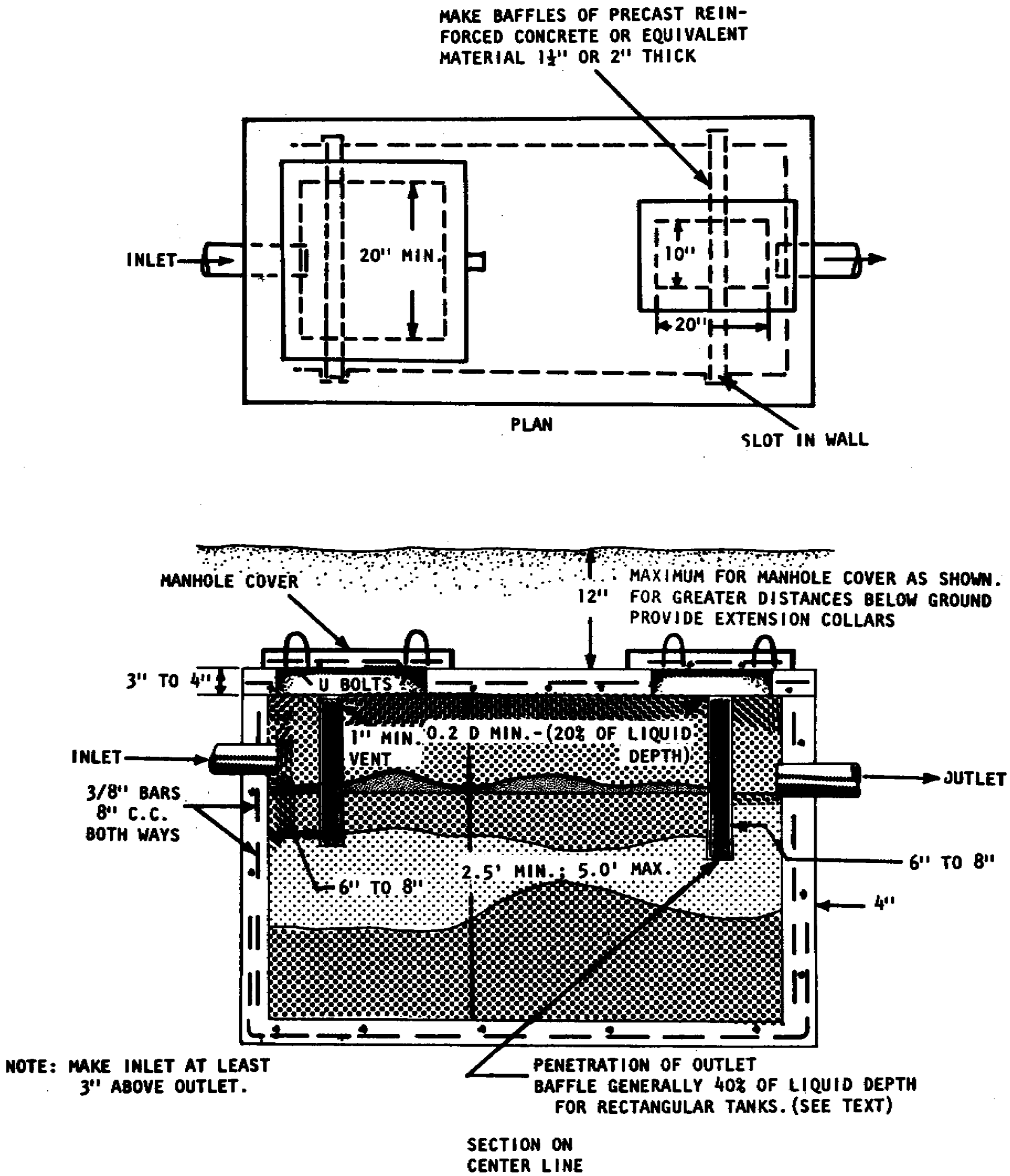


Figure 1-14. Household septic tank.

tank with the first compartment equal to 1/2 to 2/3 of the total volume provides better nonfiltrable residue removal. The compartments may be individual tanks placed in series or sections enclosed in one continuous shell with watertight partitions separating the compartments (see Figure 1-15). Although capacity is the major consideration in selection of a tank, the following points are also important.

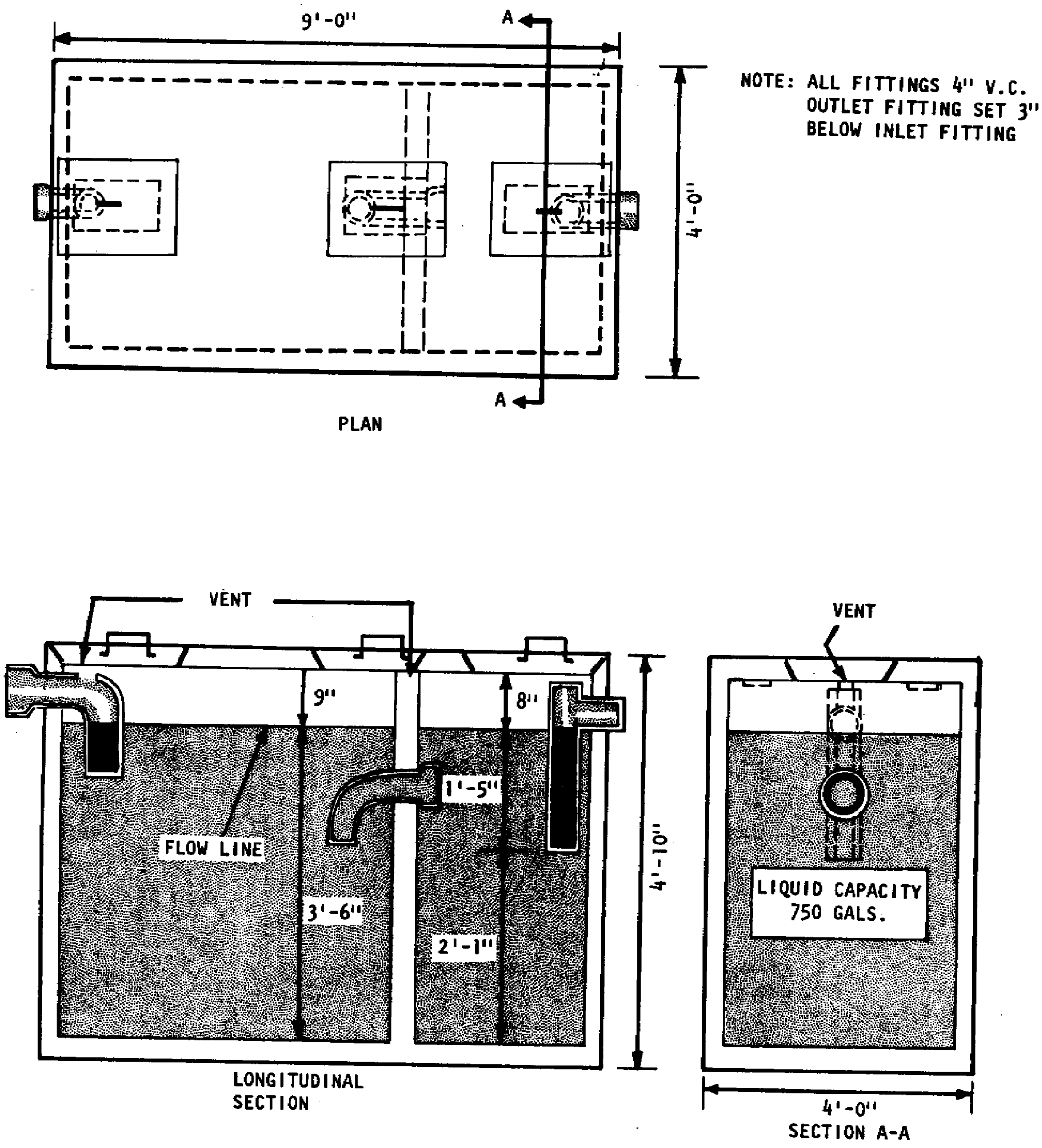


Figure 1-15. Septic tank with 2 compartments.

(1) Tank proportions. For tanks of a given capacity, shallow tanks function as well as deep. However, it is recommended that the liquid depth range between 30 and 60 inches and that the minimum plan dimension be at least 2 feet.

(2) Storage above liquid level. Capacity is required above the liquid level to provide for that portion of the scum that floats above the liquid. To allow for this scum storage, the distance from the liquid level to the top of the tank should be approximately 20 percent of the liquid depth (21 percent of the diameter for horizontal cylindrical tanks).

(3) Inlet. The inlet invert should enter the tank at least 3 inches above the liquid level to allow for momentary rises in level during discharges into the tank. A vented inlet tee or baffle should be provided to divert the incoming wastewater downward. It should penetrate at least 6 inches below the liquid level, but in no case should the penetration be greater than that allowed for the outlet device.

(4) Outlet. The outlet device (or baffle) should extend to a distance below the liquid level equal to 40 percent of the liquid depth (35 percent for horizontal cylindrical tanks) to provide a balance between scum and sludge storage.

e. **Cleaning.**

(1) Septic tanks should be cleaned before too much sludge or scum is allowed to accumulate. If either the sludge or the scum approaches too closely to the bottom of the outlet device, particles will be scoured into the disposal field and will clog the system. Eventually, when this happens, liquid may break through to the ground surface and wastewater may back up in the plumbing fixtures. When a disposal field is clogged in this manner, it is not only necessary to clean the tank, but it also may be necessary to construct a new disposal field. The tank capacities, as given before, will ensure a reasonable period of good operation before cleaning becomes necessary. There are wide differences in the rate that sludge and scum will accumulate from one tank to the next. Tanks should be inspected at least once a year and cleaned when necessary. The only way to determine definitely when a tank needs to be cleaned is to measure the depth of the scum and sludge. The tank should be cleaned if:

(a) The bottom of the scum mat is within approximately 3 inches of the bottom of the outlet device, or

(b) Sludge comes within the limits specified in Table 1-6.

(2) Scum can be measured with a stick to which a weighted flap has been hinged or with any device that can be used to feel out the bottom of the scum mat. The stick is forced through the mat, the hinged flap falls into a horizontal position, and the stick is raised until the resistance from the bottom of the scum is felt. With the same tool, the distance to the bottom of the outlet device can be found.

Liquid capacity of tank, gallons	Liquid depth in feet 2 1/2	3	4	5
750	5*	6*	10*	13*
900	4*	4*	7*	10*
1,000	4*	4*	6*	8*

* Distance from bottom of outlet device to top of sludge, in inches.

Table 1-6. Allowable sludge accumulation.

(3) A long stick wrapped with rough, white toweling and lowered to the bottom of the tank will show the depth of the sludge and the liquid depth of the tank. The stick should be lowered behind the outlet device to avoid scum particles. After several minutes, remove the stick carefully. The sludge line can be distinguished by sludge particles clinging to the toweling.

(4) Cleaning is usually accomplished by pumping the contents of the tank into a tank truck. Septic tanks should be washed or disinfected after pumping. A small residual of sludge should be left in the tank for seeding purposes. The material removed may be buried in an approved sanitary wastewater system. Spillage and leakage during pumping and transporting should be avoided. When a large septic tank is being cleaned, care should be taken not to enter the tank until it has been thoroughly ventilated and gases have been removed to prevent explosion hazards or asphyxiation of the workers. Anyone entering the tank should have one end of a rope tied around his waist with the other end held above ground by another person. An atmosphere-supplying or self-contained breathing apparatus should be used.

1-16. DOSING TANKS

When the quantity of wastewater exceeds the amount that can be disposed of in about 500 linear feet of tile, a dosing tank should be used in conjunction with the septic tank in order to obtain proper distribution of wastewater throughout the disposal area and give the absorption bed a chance to rest or dry between dosings. The dosing tank should be equipped with an automatic siphon that discharges the tank once every 3 or 4 hours. The tank should have a capacity equal to about 60 to 75 percent of the interior capacity of the tile to be dosed at one time. Where the total length of tile lateral exceeds 1,000 feet, the dosing tank should have 2 siphons dosing alternately and each serving a half of the field. Figure 1-16 illustrates a septic tank with a dosing tank and automatic siphon.

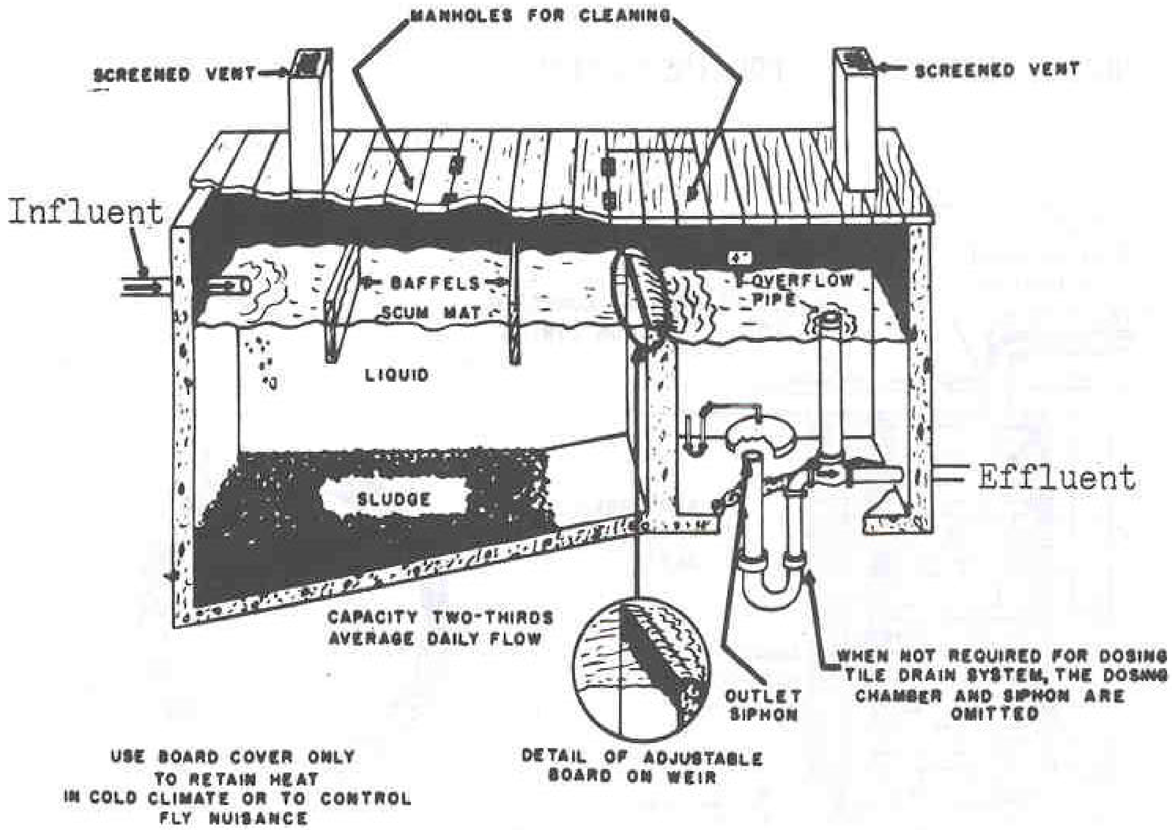


Figure 1-16. Septic tank with dosing tank and automatic siphon.

1-17. ALTERNATE DISPOSAL METHODS

a. **Seepage Beds and Seepage Pits.** When the available land area is insufficient to accommodate a complete soil absorption system, but the soil percolation test indicates an acceptable percolation rate, the following alternatives may be considered.

(1) Seepage bed. A seepage bed is essentially the same as an absorption trench except that it consists of a wider trench in which several distribution lines are laid. Distribution lines are placed 6 feet apart and 3 feet from the bed sidewall. Otherwise, the construction criteria are the same as for absorption trenches. The same amount of bottom absorption area is required (see Tables 1-3 and 1-4), but the wide bed makes more efficient use of land than a series of trenches with wasted land between the trenches.

(2) Seepage pit. A seepage pit (see Figure 1-17) is a vertical cylindrical pit constructed of unmortared masonry. The pit is surrounded by 6 inches of rock or gravel fill on the sides and 12 inches underneath. The entire surface area, both sides and bottom, is considered absorption area and permits seepage of septic tank effluent for further percolation through the gravel and surrounding soil. The seepage pit should

never be used where there is a likelihood of contaminating underground waters or where adequate absorption trenches or seepage beds can be provided. In many localities, seeping beds are prohibited. They are seldom permitted in new construction, being authorized only as an expedient measure where a soil absorption system has failed and space is not adequate for a new one.

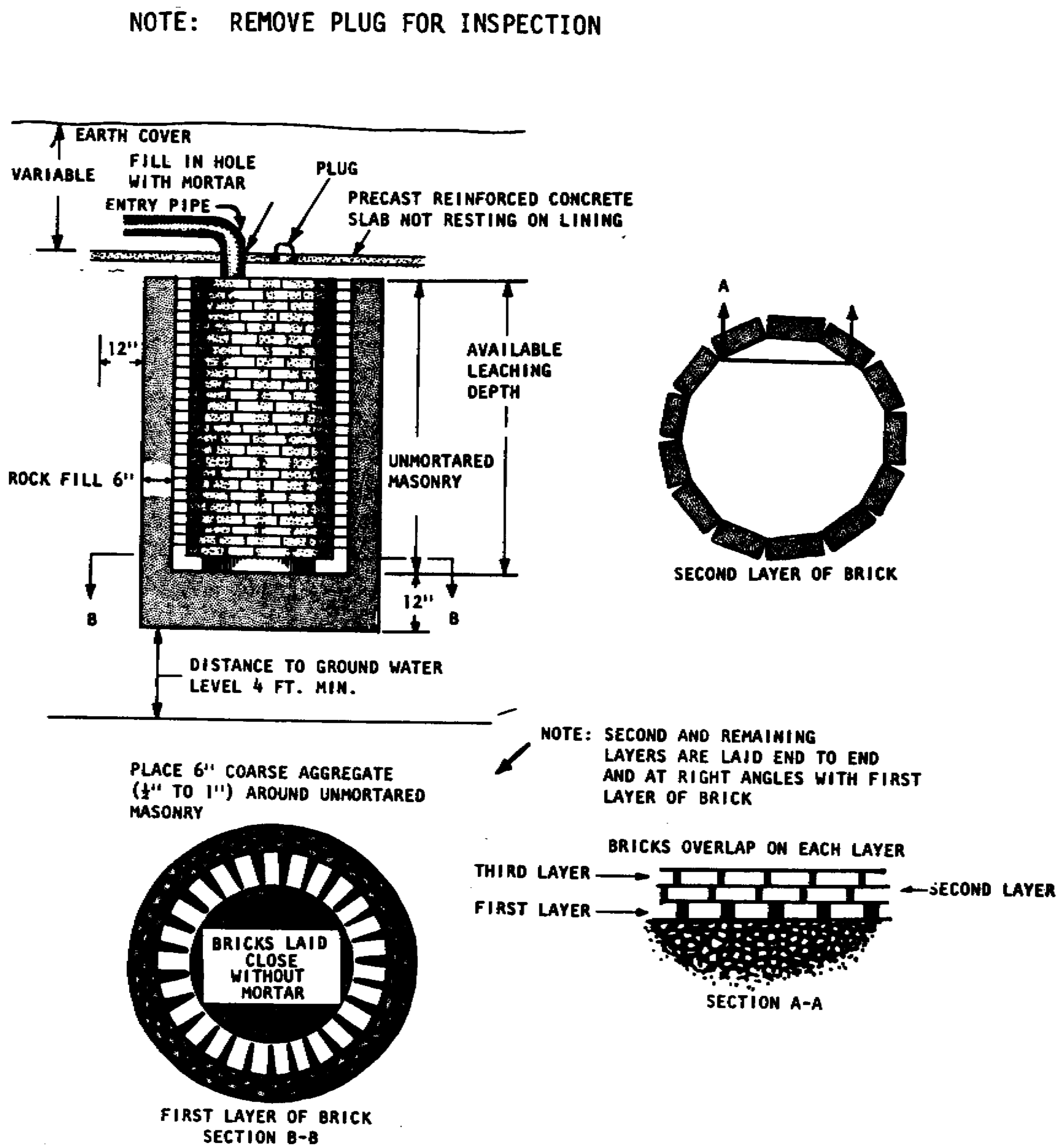


Figure 1-17. Seepage pit.

b. **Sand Filter Trenches and Subsurface Sand Filters.** In soil that is relatively impermeable, neither absorption trenches, seepage beds, nor seepage pits are satisfactory. When absorption systems are impracticable, the possibility of treating the tank effluent in subsurface sand filters or filter trenches may be considered. (Soil testing is a mandatory prerequisite for any subsurface disposal of waste.) These systems are similar to soil absorption systems except that they are deeper, generally somewhat wider, contain an intermediate layer of sand as filtering material, and are provided with underdrains for carrying off the filtered effluent. For this reason, effluent from a properly designed system can sometimes be disposed of without further treatment. In some jurisdictions, chlorination of the effluent is required.

(1) Sand filter trenches. Sand filter trenches (see Figure 1-18) are essentially wide absorption trenches (30 to 60 inches wide) underdrained with at least 24 inches of filter and below which open-joint tile lines laid in gravel collect and carry away the filtered effluent.

(2) Subsurface sand filters. These systems (see Figure 1-19) are essentially the same as seepage beds underdrained by 24 to 30 inches of filter sand and open-joint tile lines similar to those used in filter trenches. As a rough guide, subsurface sand filters should be used instead of sand filter trenches when the filter area or length of tile is enough to require the use of dosing siphons (over 1,800 square feet or over 300 feet of tile). However, clogging and installation costs are significant disadvantages for these filters.

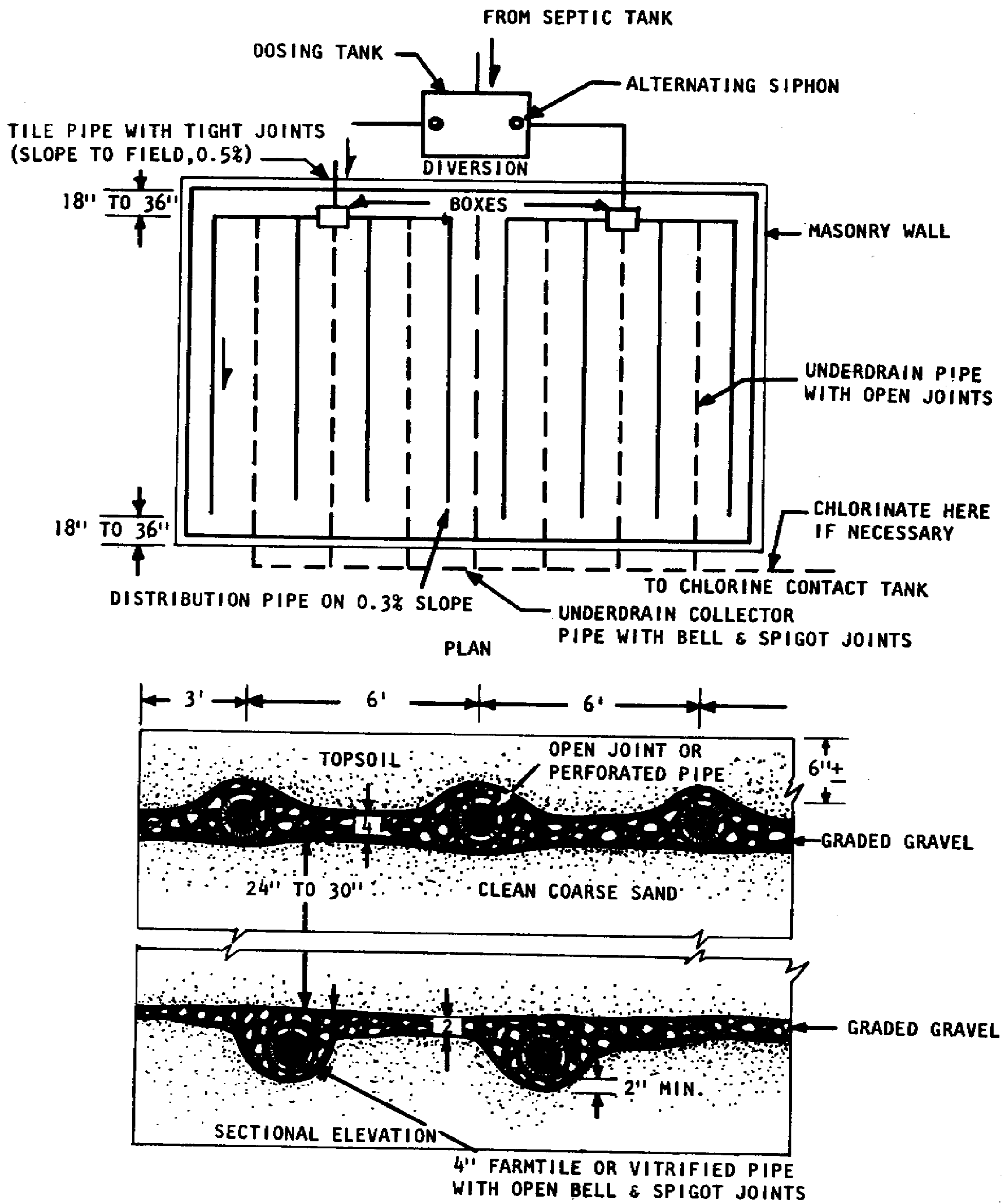


Figure 1-18. Underdrained sand filter trench.

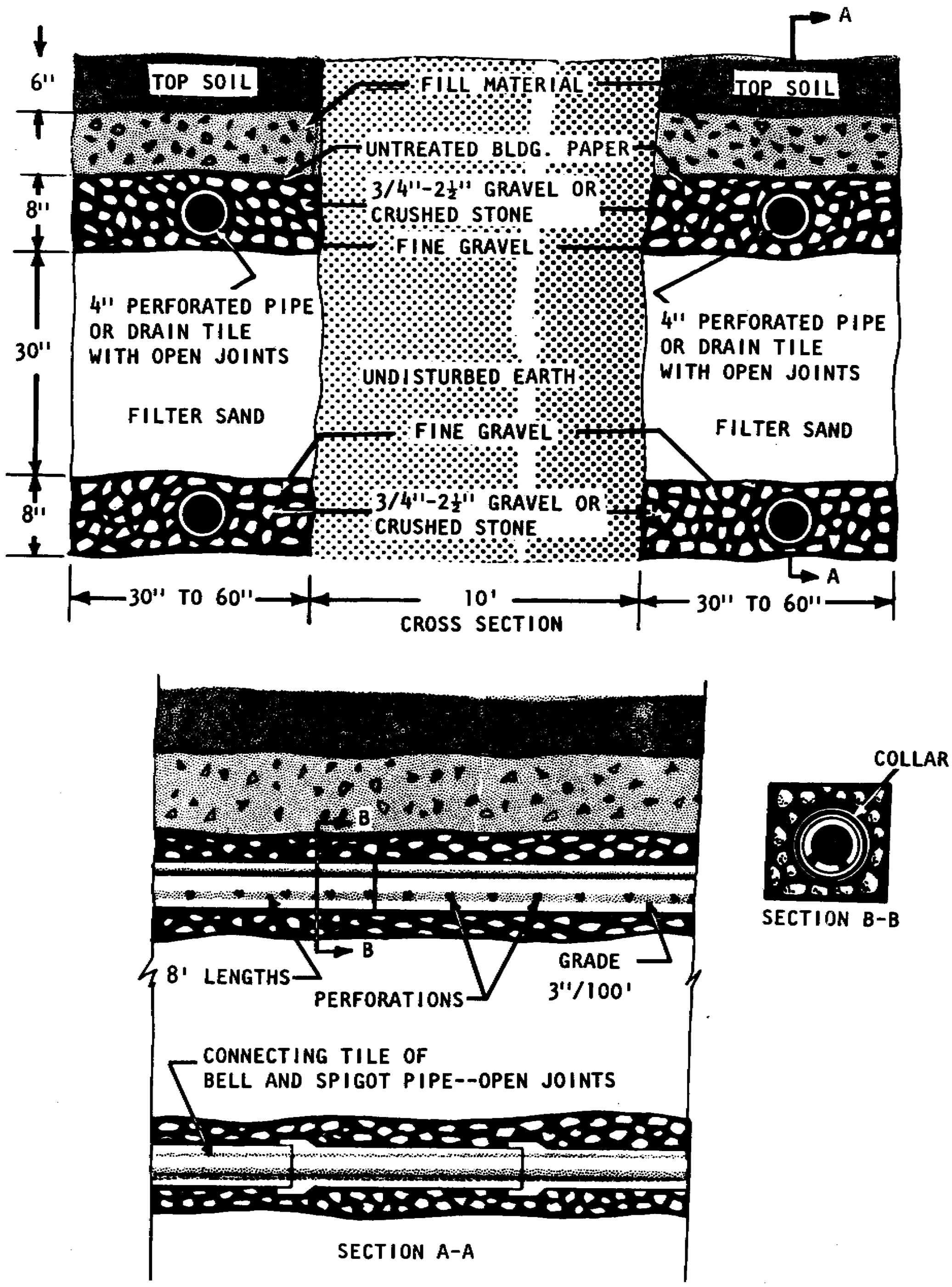


Figure 1-19. Subsurface sand filter.

Continue with Exercises

EXERCISES, LESSON 1

INSTRUCTIONS: Answer the following exercises by marking the lettered response that best answers the question or best completes the statement or by writing the answer in the space provided.

After you have completed all these exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. Which of the following is a responsibility of the preventive medicine specialist?

   a. The health of the command.

   b. The operation of wastewater treatment facilities.

   c. The collection of wastewater samples for analysis.

   d. The conduct of investigations of wastewater treatment facilities.

2. Which component of wastewater creates a public health hazard?

   a. Grease.

   b. Bacteria.

   c. Sand and grit.

   d. Inorganic solids.

3. Normal sanitary wastewater is approximately ____________ percent water.

4. The organic and mineral matter in wastewater is comprised of about _______ percent filtrable residue and about _________ percent of nonfiltrable residue.

5. Wastewater which has become stale and odorous because of anaerobic decomposition is said to be ____________________________________.

6. At which time can the wastewater flow be expected to be greatest?

   a. 0200 hours.

   b. 0700 hours.

   c. 1500 hours.

   d. 2100 hours.

7. Federal guidelines state that the effluent from a wastewater treatment plant, which is discharged into a receiving stream, should meet ______________, ___________, and _________________ discharge criteria.

8. What are the essential functions of a complete wastewater system?

   a. ____.

   b. ____.

   c. ____.

   d. ____.

9. Average raw wastewater has a 5-day BOD content of approximately:

   a. 25-50 mg/l (ppm).

   b. 50-100 mg/l (ppm).

   c. 150-250 mg/l (ppm).

   d. 500-1,000 mg/l (ppm).

10. Which of the following are primary wastewater treatment processes? (More than one response may be correct.)

a. Aeration.

b. Filtration.

c. Chlorination.

d. Sedimentation.

e. Sludge removal.

f. Sludge digestion.

g. Screening and grinding.

11. What wastewater treatment process removes contaminants that were not removed by primary and secondary processes? ______________________

12. Properly controlled chlorination of a wastewater treatment plant effluent will reduce the bacterial content by about __________________ percent.

13. Which wastewater treatment processes occur within the septic tank? (More than one response may be correct.)

a. Primary.

b. Secondary.

c. Tertiary.

14. When can a septic tank system be used effectively? (More than one response may be correct.)

    a. Adequate space is available.

    b. The soil has adequate absorptive properties.

    c. The ground water table is at least 50 feet below the surface.

15. In conducting a percolation test, you should determine the percolation rate _____ hours after water is first added to the hole

    a. 4.

    b. 8.

    c. 12.

    d. 24.

16. If a percolation test hole has water standing in it after the overnight swelling period, the percolation rate is determined from the drop in water level that occurs during:

    a. The first hour.

    b. The first 30 minutes.

    c. The final 30 minutes of a 4-hour time span.

    d. An average 30-minute period over a 4-hour time span.

17. How far should a wastewater absorption field be located from a well?

a. 5 feet.

b. 25 feet.

c. 50 feet.

d. 100 feet.

18. How many square feet of absorption area are required for a septic tank system serving a small unit having a wastewater flow of 10,000 gallons per day, using soil with a percolation rate of 4 minutes per inch of fall? The unit is equipped with garbage grinders in the dining facility.

____________________ square feet

19. How many linear feet of absorption trench does the unit described in exercise 18 need if the trenches used are 3 feet wide?

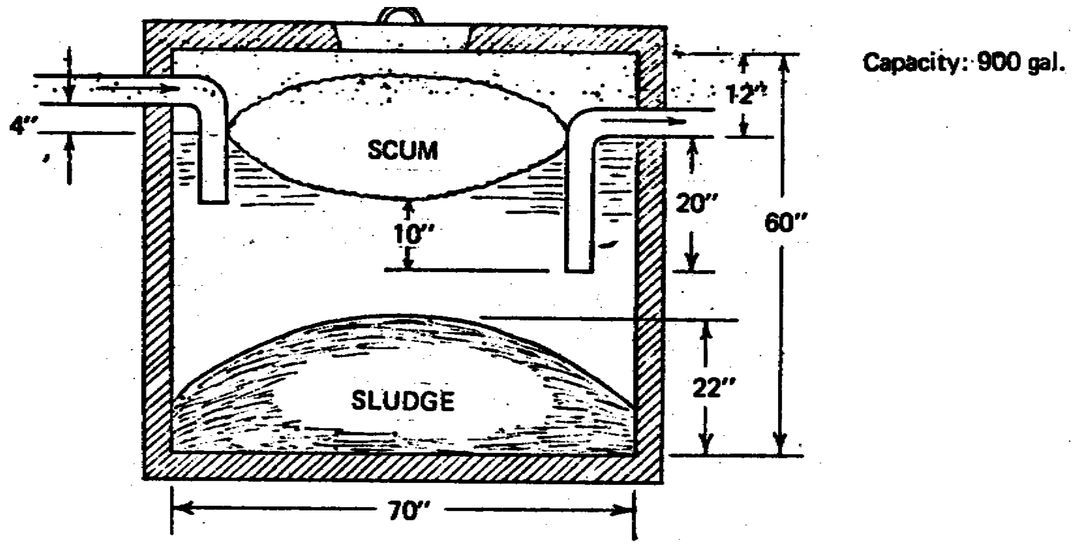
____________________ feet

20. A septic tank should be located no closer than _________________ feet to any source of water supply.

21. If the per capita flow of wastewater is 100 gallons per day, what is the minimum recommended capacity of a septic tank serving 50 persons?

____________________ gallons

22. Does the septic tank illustrated below need cleaning? ___________________



23. A septic tank system is to be installed to serve a small unit with an average wastewater flow of 1500 gallons per day. A 2,500 gallon septic tank will be installed. The soil percolation rate is 30 minutes per inch. Absorption trenches will be 36 inches wide. Will this septic tank require a dosing tank? _____________

If so, how many siphons will be required? _______________________

24. A small unit requiring a septic tank system finds that the soil percolation rate exceeds 60 minutes per inch. Which options may be used?

a. Seepage beds.

b. Seepage pits.

c. Absorption trenches.

d. Sand filter trenches.

e. Subsurface sand filters.

25. Using the information described in exercise 24, what additional provision must be made to the effluent?

____.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 1

1. c (para 1-3c(3))

2. b (para 1-5c)

3. 99.9 (para 1-5d)

4. 60, 40 (para 1-5d(1), (2))

5. septic (para 1-5c)

6. b (para 1-6b)

7. Federal, state, local (para 1-8)

8. a. Collection.
   b. Transportation.
   c. Treatment.
   d. Disposal. (para 1-9)

9. c (para 1-5b(2))

10. d
    e
    g Sedimentation and sludge removal are physical processes and a basic part of primary treatment; however, they are also employed in conjunction with secondary processes (secondary settling following filtration or aeration). (para 1-10a)

11. tertiary (para 1-10c)

12. 99.5 (para 1-10c(6))

13. a
    b The settling of solids in primary; the sludge digestion is secondary. (para 1-12b)

14. a (para 1-12b)
    b The ground water table should be at least 4 feet below the bottom of absorption trenches (para 1-13a). Soil absorption systems may be adapted to sloping ground (para 1-14b, see Figure 1-11).

15. d (para 1-13b(4))

16. b (para 1-13b(5)(a))

17. d (para 1-14b; Table 1-2)

18. 4,800 (para 1-14d(2)); Table 1-4)
4 min/in.=2.5 gal/sq ft/da
10,000 gal/da/2.5 gal/sq ft/da=4,000 sq ft
.20 x 4,000 sq ft = 800 sq ft (for garbage grinders)
4,000
4,800 sq ft

19. 1,600 (para 1-14c)
4,800 sq ft/3 ft = 1,600 linear feet

20. 50 (para 1-15b; Table 1-2)

21. 4875 (para 1-15c; see Figure 1-13)
50 persons x 100 gal/person/da=5,000 gal/da
Enter Figure 1-13 at a flow of 5,000 gal/da
Read up to curve and interpolate tank capacity
Or use the formula V=1125 + 0.75Q = 1125 + 0.75 (5000)=
1125 + 3750 = 4875

22. Yes (para 1-15e(1); Table 1-6) liquid depth: 48 in (60-12);
capacity: 900 gal;
top of sludge is 22 in. from bottom;
The bottom of outlet device is 28 in. from bottom 60-(12+20). The top of the sludge is 6 inches from the bottom of the outlet device (28-22) which is less than recommended minimum of 7 inches.

23. Yes 1 siphon. (para 1-16)
30 min/in. = 0.9 gal/sq ft/da (Table 1-4)
1500 gal/da/0.9 gal/sq ft/da = 1667 sq ft
1667 sq ft/3 ft = 556 linear feet

24. d,e (para 1-13a, 1-17b). Soil absorption systems are unsatisfactory when the percolation rate exceeds 60 min (30 min for seepage pits).

25. Disposal of the effluent (and chlorination, if necessary) (para 1-17b)

End of Lesson 1

LESSON ASSIGNMENT

LESSON 2 Wastewater Treatment Plant Operation.

TEXT ASSIGNMENT Paragraphs 2-1 through 2-24.

LESSON OBJECTIVES After completing this lesson, you should be able to:

2-1. Identify basic principles and component parts of a conventional wastewater treatment plant.

2-2. Identify the design features and function of each component part of a conventional wastewater treatment plant.

2-3. Identify proper procedures in wastewater treatment plant sampling.

SUGGESTION After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 2

WASTEWATER TREATMENT PLANT OPERATION

Section I. PRIMARY WASTEWATER TREATMENT

2-1. GENERAL

Primary wastewater treatment is essentially a physical process even though a limited amount of biochemical activity characteristic of secondary treatment sometimes occurs. Primary treatment operation at the plants include screening and grinding to remove larger floating solids; velocity reduction to remove grit, sand, and cinders; a means to measure the amount of incoming wastewater; primary clarification/sedimentation to remove settleable residue; and removal of sludge from the settling tanks. The units will need to be maintained for maximum production.

2-2. SCREENING AND GRINDING

Wastewater treatment plants are equipped with screens, grinders, or shredders. Their function is to prevent the entrance into the plant of large objects (pieces of wood, rags, dead animals, etc.) which may clog pipes or damage pumps and other equipment.

a. **Shredders (External).** These units are located outside the wastewater flow path and receive large objects that need to be shredded or grounded prior to being returned to the wastewater flow for further treatment. Except at large plants, shredders are operated only when enough screenings have been collected to justify operation. Shredders are carefully washed, cutting edges inspected and adjusted, and parts lubricated according to manufacturer's instructions after each run.

b. **Screens.** There are several types of screens such as bar, fixed-bar, and fine screens. The most commonly used type of screen is the fixed-bar screen. This type of screen usually consists of a grid of steel bars spaced on centers varying from 3/4 to 2 1/2 inches. It is installed at an angle in the direction of the flow of the wastewater influent (see Figure 2-1). Fine screens are not used during this process.

(1) Need for frequent cleaning. In small installations, screens are hand-cleaned. At larger plants, they are usually cleaned mechanically by rakes that traverse the screens either continuously or intermittently. The bar screen must be kept clear by raking at frequent intervals. Neglect of cleaning may cause wastewater to back up in the influent pipe and overflow the screen chamber. Clogged bar screens cause material to settle in the influent line where it becomes septic and odorous. This septic material is suddenly washed into following elements of the treatment plant when the screen is cleared. This is objectionable because best plant performance is secured when the wastewater is received fresh and in uniform strength.

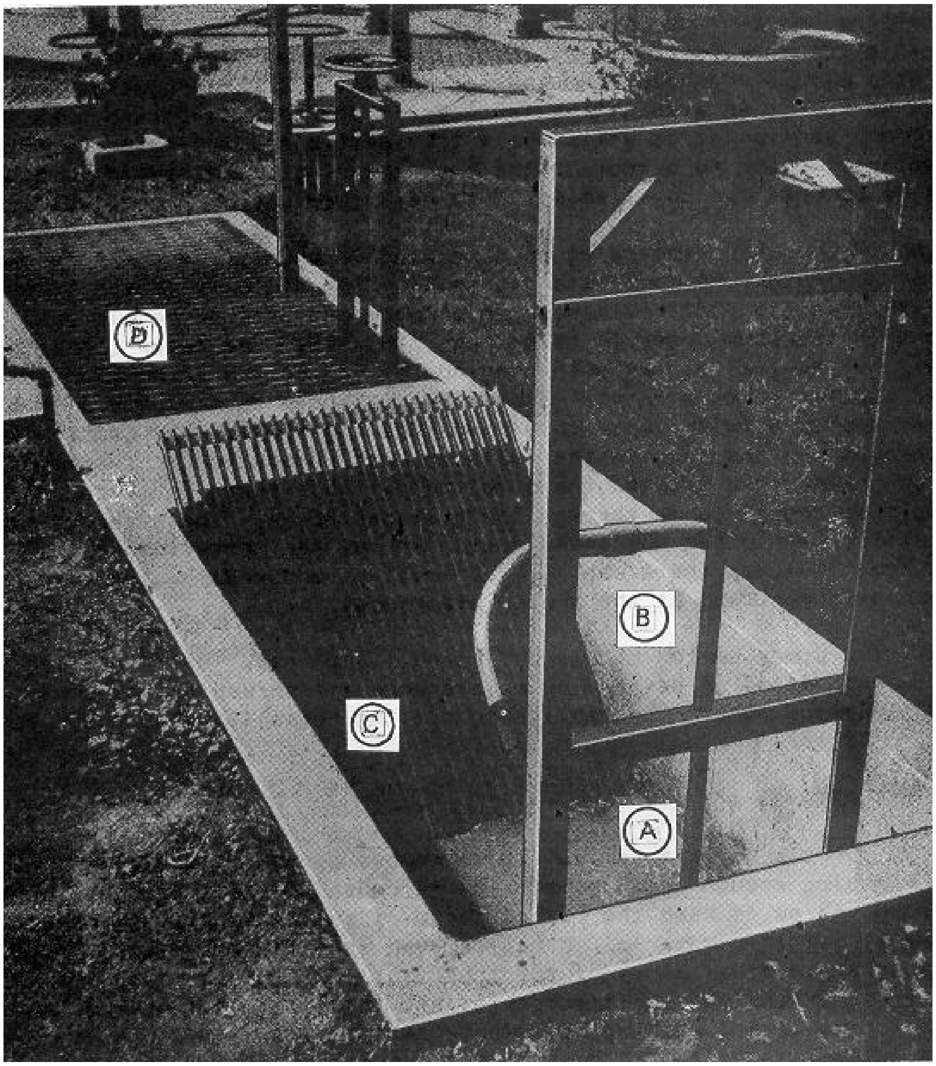


Figure 2-1. Bar screen, hand cleaned type. (A) wastewater stream, (B) screen chamber, (C) bar screen, and (D) drainage platform.

(2) Screen cleaning. Screenings should be raked off the screen and onto a drainage platform. As soon as most of the water has drained, screenings should be placed in a receptacle (such as a trashcan) and covered to await disposal. The screen chamber and screen should be flushed frequently to remove grease and accumulated solids from walls and bars. Fine screens require scrubbing or brushing. Greasy tools may be cleaned with kerosene.

(3) Disposal of screenings. Screenings contain putrescible material and must be disposed of daily in a sanitary manner. At small installations, screenings are commonly buried. Use of the sanitary fill is appropriate for this purpose. At large installations, they may be incinerated with sludge gas from the secondary treatment processes being utilized as fuel. An alternative is to grind the screenings and pass them into primary sedimentation units where they settle and are later digested with

other solids. Under no circumstances may screenings be disposed with garbage that is to be used for hog feeding or to be plowed under in cultivated land.

c. **Comminutor.** Grinding or shredding is usually done with a device called a *comminutor*. A comminutor is usually installed in conjunction with a bar screen (see Figure 2-2). In such an arrangement, the screen is available for use when the comminutor is being required. The comminutor consists of a vertical, cylindrical screen with openings of 1/3 to 3/8 inch that is revolved rapidly by an electric motor. The cylinder is equipped with sharp teeth which pass between teeth in a comb (see Figure 2-3). The waste stream flows through the openings in the cylinder, but solids larger than the holes are thrown repeatedly between the comb and cylinder teeth until the solids are shredded fine enough to go through the cylinder holes. The shredded material later settles with other suspended matter in the sedimentation basins. Maintenance includes cleaning, lubricating, and keeping the cutting edges in proper alignment and at the proper clearance.

CAUTION: The power switch should be locked in the open (OFF) position when inspecting or performing maintenance on all shredding equipment. Replace worn or nonrealigning cutting edges (blades, shear bars, and plates).

2-3. GRIT REMOVAL

The purpose of grit removal is to remove as much grit as possible without removing enough organic material to cause odor and disposal problems. Grit removal helps to keep the moving parts of the wastewater equipment free from damage. If this material is not removed from the wastewater, troublesome deposits occur in other parts of the treatment plant where removal is laborious and expensive. Grit accumulations from grit chambers not having mechanical removal and washing equipment contain sufficient organic matter to create a nuisance condition. Such grit is usually carted away and buried. Grit that is continuously removed from grit basins by mechanical equipment, and which has been thoroughly washed is not objectionable. It is commonly used for filling or leveling of low places in the wastewater plant area. The two grit removal units (the flow rate controlled and the aerated units) are noted below. As with any equipment, it will need to be cleaned, adjusted, and lubricated according to the manufactured instructions or standing operating procedures (SOP).

a. **Grit Chamber (Flow Rate Controlled).** A grit chamber (see Figure 2-4) is an enlarged channel or long tank commonly located immediately following the screening apparatus and immediately preceding the sedimentation basin. The chamber is used primarily to remove suspended inorganic matter from wastewater. It is designed to reduce or slow the flow velocity of the wastewater just enough to let suspended inorganic material gravel, and cinders settle to the bottom for removal. Grit, except very finely divided material, settles quickly when the flow velocity is reduced to about one foot per second. The flow is not retarded further because slower velocities would let organic solids settle.

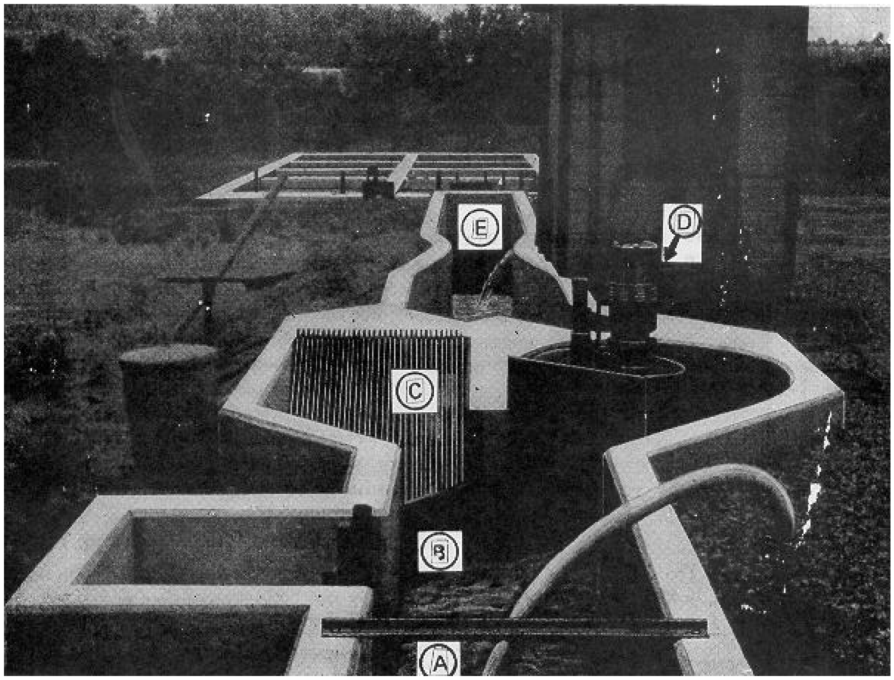


Figure 2-2. Comminutor and bar screen. (A) Wastewater from collection system, (B) weir, (C) bar screen, (D) comminutor motor, (E) Parshall flume.

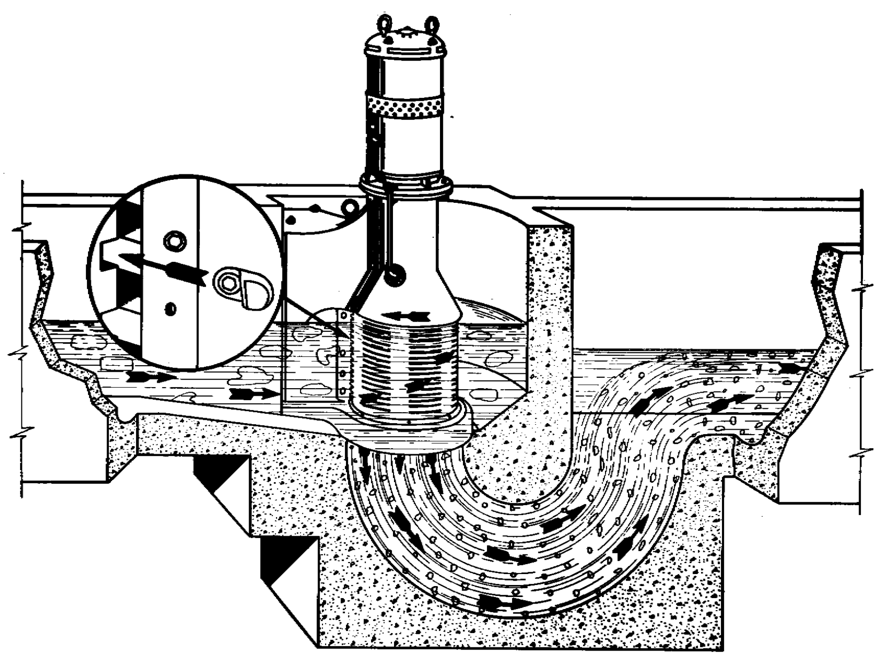


Figure 2-3. Sectional drawing of comminutor. (Note schematic difference in size of solids before and after shredding.)

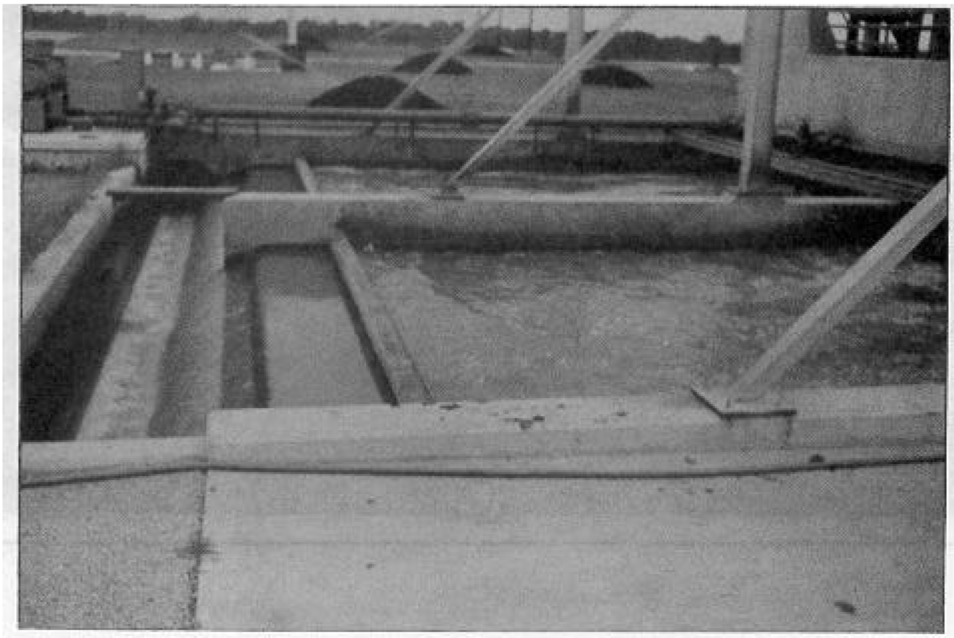


Figure 2-4. Grit chamber.

b. **Preaeration Tanks.**

(1) Preparation. At some Army installations, air is sometimes forced into the wastewater in one of several ways before the wastewater undergoes primary sedimentation (para 2-5). Specially designed preaeration tanks also serve as grit chambers. Preaeration is done when it is necessary to keep wastewater fresh or to freshen it up by adding air (oxygen). Much of the oxygen content of the air forced into the wastewater dissolves in the wastewater. This dissolved oxygen (oxygenation) keeps the wastewater from becoming stale. The rolling action of the aeration tank causes the particles to collide many times and thus scour (clean) the grit.

(2) Disadvantage of preaeration. Grease, which usually settles with the solids during the primary sedimentation process, rises to the top of preaerated wastewater. Removal of grease by preaeration helps make secondary treatment more effective, but the extra labor and power necessary for disposal of the large quantity of grease is not considered justified at Army installations.

c. **Prechlorination.** Chlorine is sometimes added at the plant inlet for special purposes. This chlorination is termed prechlorination. A residual is not normally required.

(1) Low flows. When flows are below rated plant design and detention periods in primary-settling tanks are excessive, chlorine may be added at the plant inlet to keep wastewater fresh and prevent odors.

(2) Raw influent. Sometimes a treatment plant is located at such a distance from the installation or community served that the wastewater becomes stale and septic before arriving at the plant. Chlorine may be added to the raw influent in order to prevent odors and to prepare the wastewater for treatment.

(3) Filter odors. Odors may be particularly objectionable from fixed-nozzle filter sprinklers. Partial chlorination of the filter influent will reduce them.

(4) Sewer system chlorination. Production of hydrogen sulfide and other odorous gases, septic action in the sewers, and undesirable fungus growths are correctable by chlorination of the wastewater at a manhole or in a pumping station. Chlorinating wastewater in Army systems, however, is normally not justified. Such chlorination cannot replace a regular sewer inspection and cleaning program. However, equalization is justified when contaminated storm waters or wastewaters from batch operations occur.

d. **Safety Precautions.** Safety precautions are to be followed through the wastewater treatment processes anytime chlorine is used. Although automatic chlorinators provide an efficient means of adding chlorine to wastewater, they are inherently very dangerous. They dispense chlorine gas, which is a highly poisonous chemical. The following precautions must be taken to protect personnel working around the equipment.

(1) Room separation. If chlorinators and/or cylinders are in a building used for other purposes, a gas-tight partition separating the chlorine room from all other portions of the building is needed. Doors to the room are to open only to the outside of the building and are to be equipped with panic hardware. The storage area is to be separated from the feed area.

(2) Inspection window. A clear glass, gas-tight window is to be installed in an exterior door or interior wall of the chlorinator room to permit the chlorinator to be viewed without entering the room.

(3) Heat. Chlorine equipment rooms are to be provided with a means of heating for room temperature to be maintained at least 60°F. This will help to prevent the formation of chlorine hydrate in the chlorinator.

(4) Ventilation. Forced mechanical ventilation providing one complete air change every three minutes is to be installed. The entrance to the air exhaust duct from the room is to be near the floor and the point of discharge is to be so located as not to contaminate the air inlet to any building or inhabited areas. Air inlets are to be so located as to provide cross-ventilation and to prevent a fan from developing a partial vacuum in the room. The partial vacuum would make it difficult to open the doors. Where duct work is required to carry air to the fan, it should be laid out and spaced so as to exhaust air from all equipment areas. Exhaust openings should be designed so that covers are not required.

(5) Electrical controls. A common control for the fans and lights keyed to an exterior lock on the entrance door is to be installed so that the fans and lights will automatically come on when the door is opened, will only be deactivated by relocking the door externally, and can also be manually operated from the outside without opening the door.

(6) Cylinder storage. A storage area is to be provided that allows for a minimum 15-day inventory of reserve and empty containers. Cylinders may be stored outdoors on suitable platforms at or above grade and under cover of a well-ventilated, fireproof structure.

(7) Use of chlorine actions. The presence of chlorine gas in the atmosphere can pose immediate and serious hazards to the health of any person breathing the air. Therefore, *precautions are required*. Gas masks approved by the National Institute for Occupational Safety and Health (NIOSH) are to be provided outside any area where an individual would be exposed in the event of chlorine leaks or spills. All rooms in which chlorine is to be stored or handled should be adequately ventilated to the outside. A fan, automatically turned on prior to entry into the chlorination or storage facility, *must* be provided. Chlorine detectors (the liquid-reagent, electrode-cell, meter type, sensitive to one ppm of chlorine by volume in air) that continuously monitor the air are to be installed to provide a visual/audible alarm in the event of a chlorine leak. The enclosed space is to be entered only if the worker is under observation by a co-worker and only if the worker has in his possession a respirator suitable for escape. When hydrochlorite compounds and generators are used, the above requirements do not apply. For safe handling of chlorine, follow local directives.

CAUTION: Chlorine gas has a suffocating odor and can kill. Be observant to all audible and visual alarms. Follow all procedures as noted above and those in the local SOP.

2-4. FLOW MEASUREMENT

Every wastewater treatment plant must have some means of measuring and recording the flow of incoming wastewater and wastewater flow throughout the plant. Such information is necessary for proper plant sampling and control as well as for planning additions to the plant. Metering of wastewater normally takes place in the influent line preceding primary settling. Two types of metering devices in common use are weirs and Parshall flumes.

a. **Weirs.** Weirs are regularly formed notches or openings placed perpendicular to a channel through which water flows (see Figure 2-5). As the flow increases, the resistance created by the weir causes the water to rise in the channel ahead of the weir. The height of the water is measured as it passes over the weir and, by means of tables, this height is converted to flow in gallons per minute or similar units.

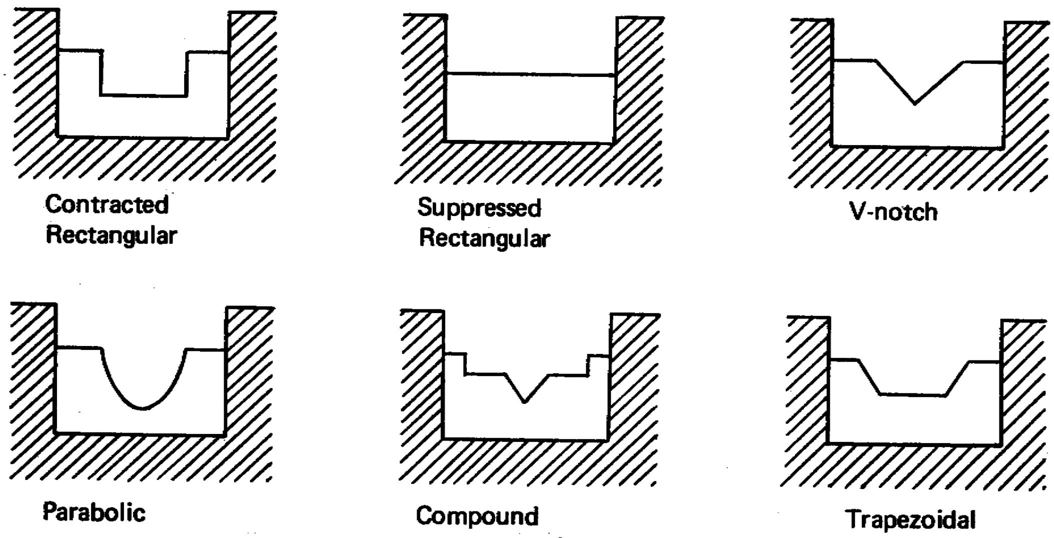


Figure 2-5. Shapes of weirs.

b. **Parshall Flume.** The Parshall flume is one of the most common means of metering wastewater flow in open channels. This flume has an open and constricted channel (see Figure 2-6) in which the difference in wastewater elevation above and below the constriction can be accurately translated into rate of flow by means of tables. The Parshall flume is preferred over the rate of flow by means of tables. The Parshall flume is preferred over the weir in that it is self-cleaning, can handle a wide variation in flow, and is useful when available the head is limited.

2-5. PRIMARY CLARIFICATION OF SEDIMENTATION

a. **Process.** Sediment is material carried in a fluid by reason of motion of the fluid. The purpose of primary clarification is to separate floating and setttleable solids from the wastewater. The objective is to clarify or settle out the sediment when the motion of the fluid lessens or stops. When fresh domestic wastewater stands quiescent or flows very slowly, a considerable portion of the suspended organic matter and the solid mineral matter remaining after grit removal settles rapidly. Floating solids may be skimmed off the top. The accumulation of nonfiltrable residues, which is called *sludge*, settles to the bottom of the tank or basin and is removed from the bottom of the tank. This sludge is still quite fluid, containing 95 percent or more of water and 4 to 5 percent (40,000 to 50,000 ppm) of solids. Most of the residue is highly putrescible organic materials. The sludge must be removed frequently to prevent septic conditions in the basin and to maintain the designed basin volume. Removal of the settleable organic sediment markedly reduces the biochemical oxygen demand of the remaining waste stream. Treatment disposal of sludge is discussed in Section II.

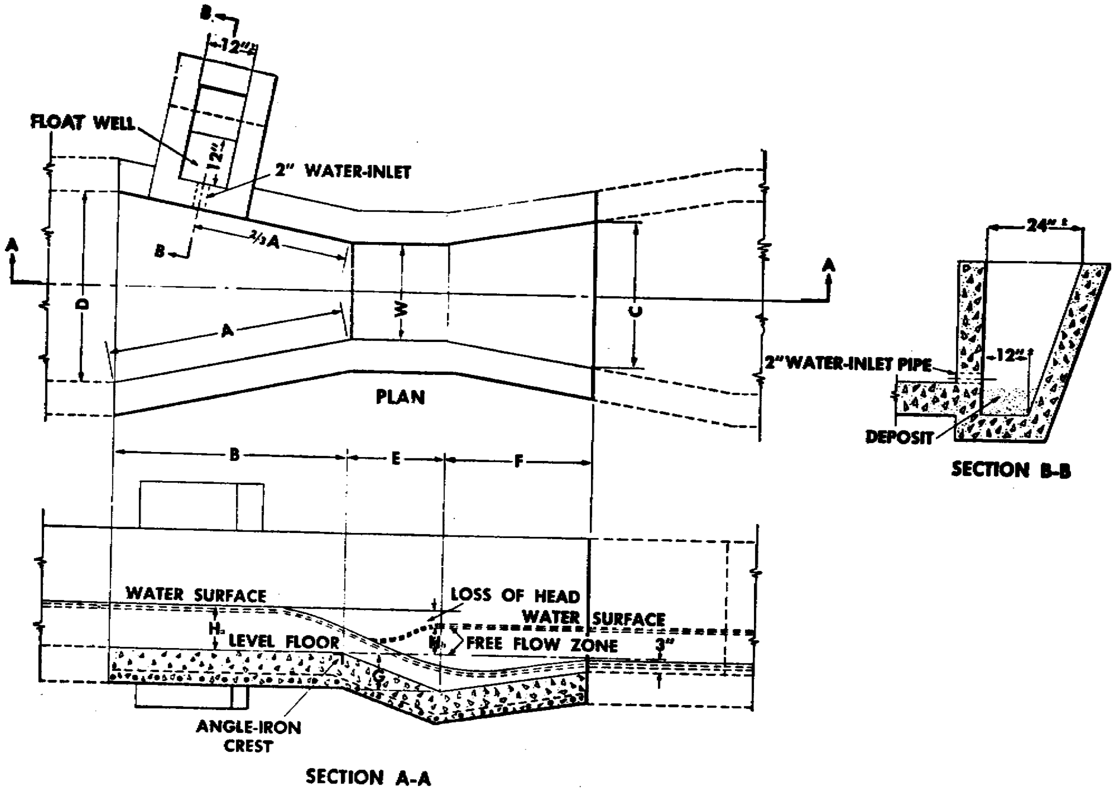


Figure 2-6. Parshall flume.

b. **Detention Time and Period.** The *detention time* is the time required to fill the tank with wastewater at a given flow or the time required for wastewater to pass through a tank. The *detention period* is the time required to displace the contents of a tank or unit at a given rate of discharge. The normal detention time for average daily flow should be 2.5 hours. Under average conditions, most of the settling in primary sedimentation tanks occurs within one hour. The quantity and rate of sedimentation after 2 hours is almost negligible. A 2-hour primary clarification period will usually effect removal of 50 to 60 percent of the suspended matter and 20 to 40 percent of the total BOD. A detention period of 2 to 3 hours in an Imhoff tank will reduce nonfiltrable residue by 45 to 60 percent. With the addition of coagulants (aluminum sulfate, ferrous sulfate, ferric chloride, and ferric sulfate, plus lime for pH adjustment) which are commonly used in water treatment processes, as much as 75 to 85 percent of the suspended matter may be removed. This process will also remove 50 to 70 percent of the total BOD.

c. **Primary Clarification Tanks.** Different shaped clarification tanks or basins are frequently employed for holding wastewater until primary settling can take place. Three designs are common -- round, rectangular, or square. The round and rectangular sedimentation tanks are used more frequently than the square one.

(1) Round or circular tanks (see Figure 2-7). The tanks are usually made of concrete, but can be made of metal. These tanks usually have mechanical conveyors. The sweeping or skimming device on the surface moves floating solids and scum to a holding tank or well for further treatment or disposal. The skimmer must be adjusted to a level position so that just enough emersion is allowed to remove all floating solids without removing too much water. The surface baffles (deflector vanes) prevent the discharge of floating solids from going over the weirs. The skimming device is attached to the same shaft that drives the sludge collection mechanism. These tanks usually have rotating scraping mechanisms which continuously force the sludge to a sump near the center of the bottom of the tank. As wastewater enters through a center pipe, the solids settle out and the sludge collecting device mechanism (scrappers and plows) removes sludge from the slopping perimeter to the sloping floor of the tank.

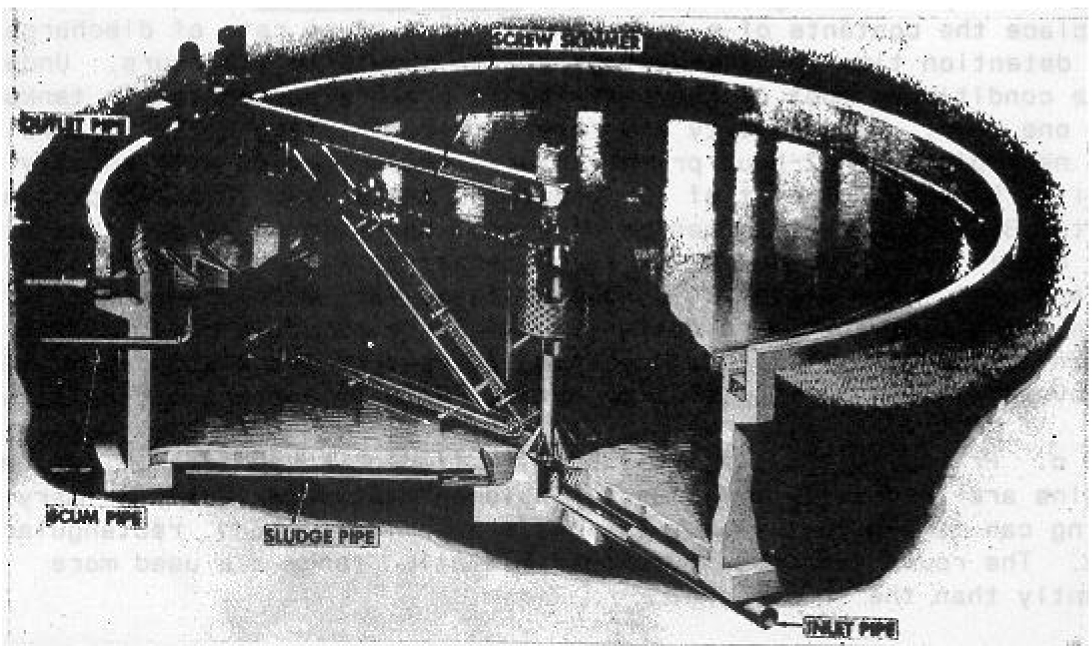


Figure 2-7. Circular primary settling tank with powered sludge scraping and scum skimming equipment.

(2) Rectangular tanks (see Figures 2-8, 2-9, and 2-10). Except for the dimensions and location of the unit, these tanks serve the same purpose and have about the same component parts as the round tanks. However, instead of circular motion removal, mechanical conveyor or rail motion is used. Floating solids are skimmed into a scum trough by the discharge end. A baffle prevents the floating solids from going over the weirs. Sludge is normally collected in a hopper at the bottom of the tank. For most rectangular clarifiers, surface skimming and sludge collecting are accomplished with chain-and-flight type devices or scrappers for larger installations. Two or more endless chains are installed crosswise from the clarifier.

(3) Imhoff tank. The Imhoff tank is a type of combination primary settling tank and sludge digester used at some Army installations. It is a two-story structure

with an upper (flowing-through) compartment for primary settling and a lower one for sludge digestion or secondary settling (see Figures 1-8 and 2-11). It may be rectangular or circular (see Figure 2-12). Solids settling from the wastewater detained in the tank pass through a slot in the hopper bottom of the flowing-through compartment. The slot is overlapped so that gas produced by and rising from the digesting sludge in the bottom compartment is diverted and does not enter the flowing-through compartment. This permits a settling of the solids that is unhampered by rising gas. The inside walls and a hopper should be scraped frequently with a squeegee to prevent build-up of septic solids. The flowing-through slot is cleaned by dropping one end of a heavy chain through the slot and dragging the chain along the length of the slot. The operation and cleaning of the digestion compartment is similar to that for separate sludge digester (para 2-14).

d. **Maintenance.** Good housekeeping at the settling tank is essential to prevent odors, flies, and unsightly appearance. Floating solids passing out with the effluent can clog filtering equipment and grease can cause ponding of filter media. Normal or regular inspecting, cleaning, adjusting, and lubricating of all mechanical equipment should be scheduled. Daily inspections for unusual noises, vibrations, and uneven action of mechanical equipment should be done. If these indications are noted, the unit should be shut off and the cause found and corrected.

(1) <u>Skimming devices</u>. Floating material must be removed once each shift or more often if present in large quantities. Some mechanical skimmers automatically remove materials to a sump for disposal; other tanks have a manually operated skimming tool. However, a hand-skimming tool (see Figure 2-8) should always be used to facilitate entrance of skimmings into the pipe or trough. When skimmings are pumped to the digester, a minimum of wastewater and wash water should go with it to prevent upsetting the digester operation. If large quantities of fairly dry skimmings tend to upset digestion, they should be collected in a covered can with openings for draining excess water and hauled to a sanitary fill or incinerator. The can must not be placed where drainage becomes a nuisance. If a fill is not available, skimmings are removed to a trench and covered with at least two feet of earth. A spray of water under pressure directed against floating material frequently settles it.

(2) <u>Perimeter and bottoms</u>.

(a) Sidewalls of channels, baffles, weirs, and tanks are kept clean of grease and other solids by hosing, scraping, or brushing once each day or more often, if necessary.

(b) Dead ends and corners are brushed at least once each shift. Fine sand and gravel are removed for burial or used as fill.

(c) Decks and walks are hosed at least once each day. Where pressure is not available for hosing, secondary effluent may be used with a portable pump, pressure system, or other pumping equipment.

(3) Grit. If grit appears in channels or hoppers, grit-chamber operation is checked.

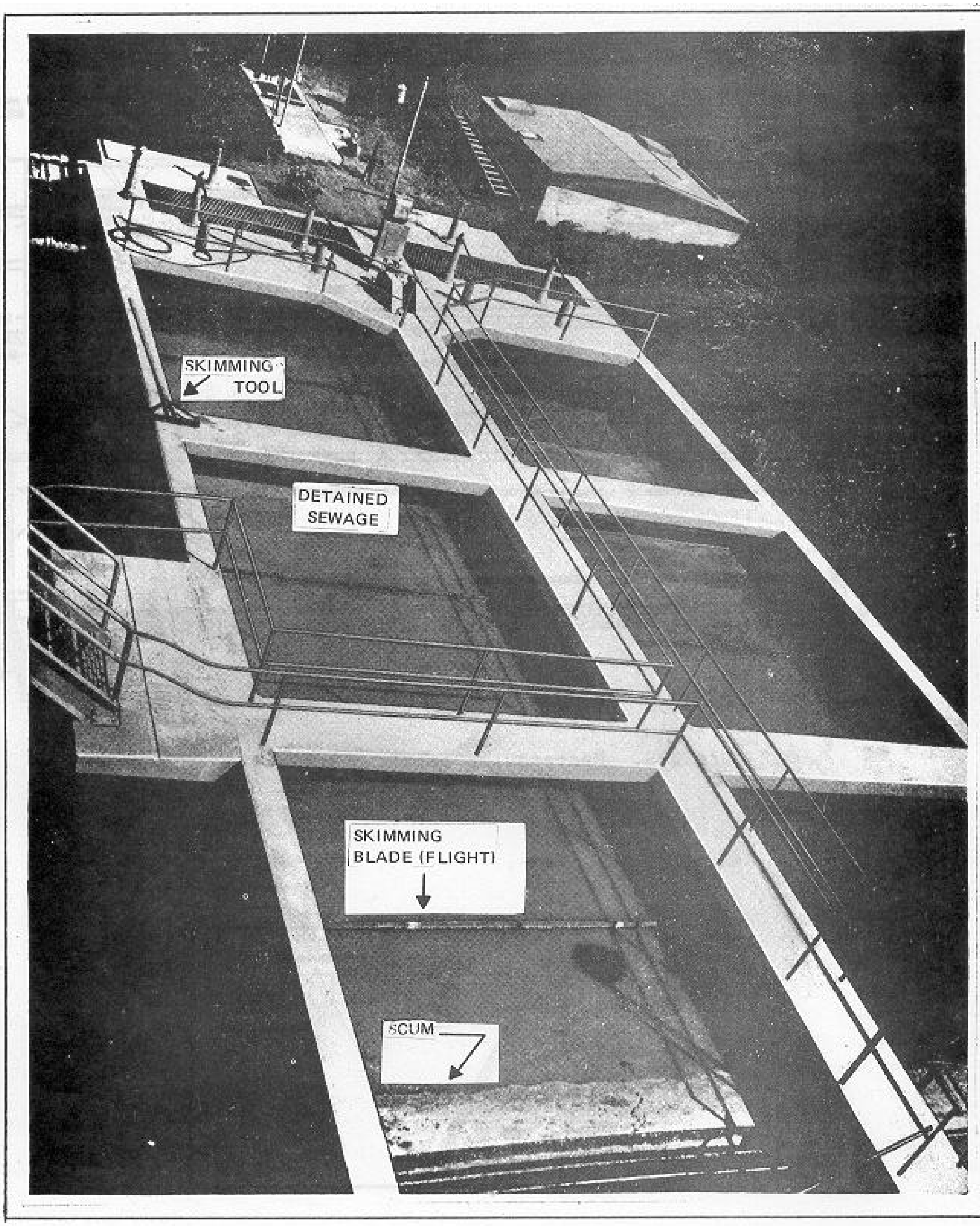


Figure 2-8. Rectangular primary settling tanks with powered skimming equipment.

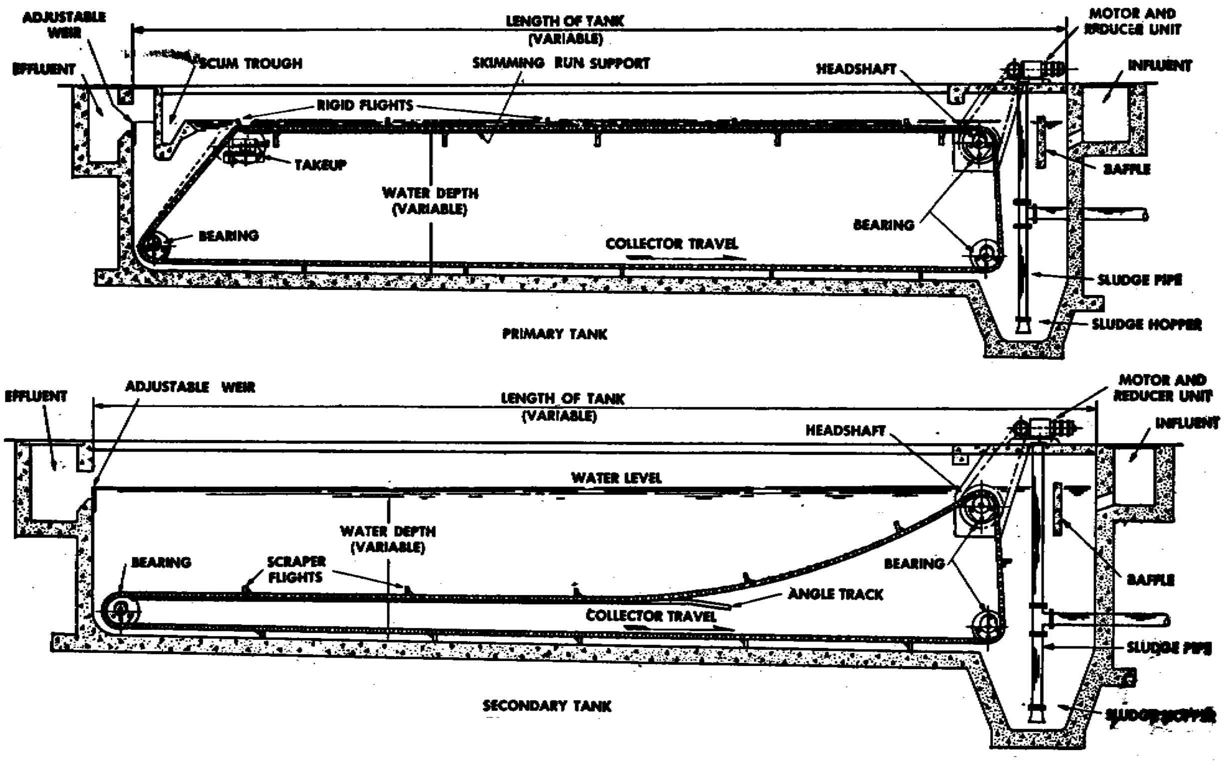


Figure 2-9. Rectangular settling tanks and mechanisms.

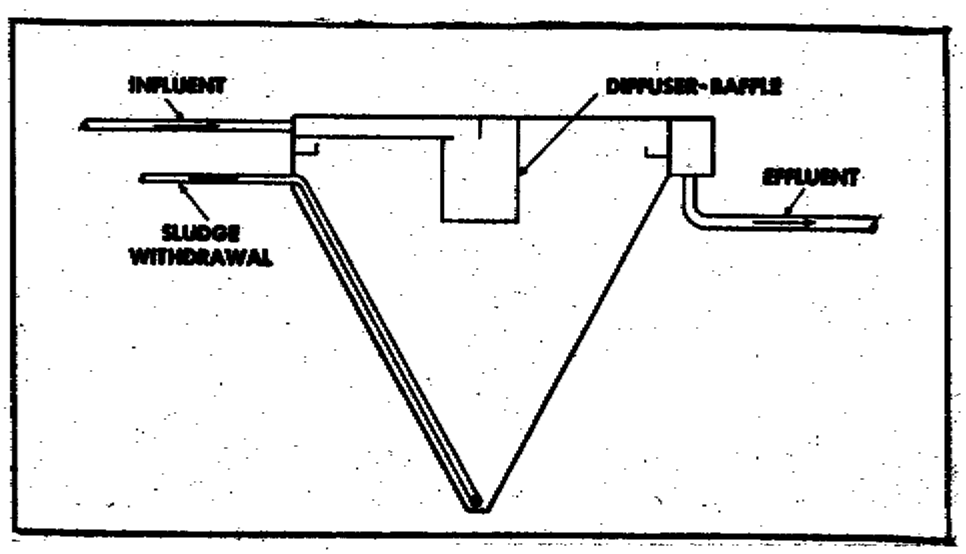


Figure 2-10. Hopper type primary settling tank.

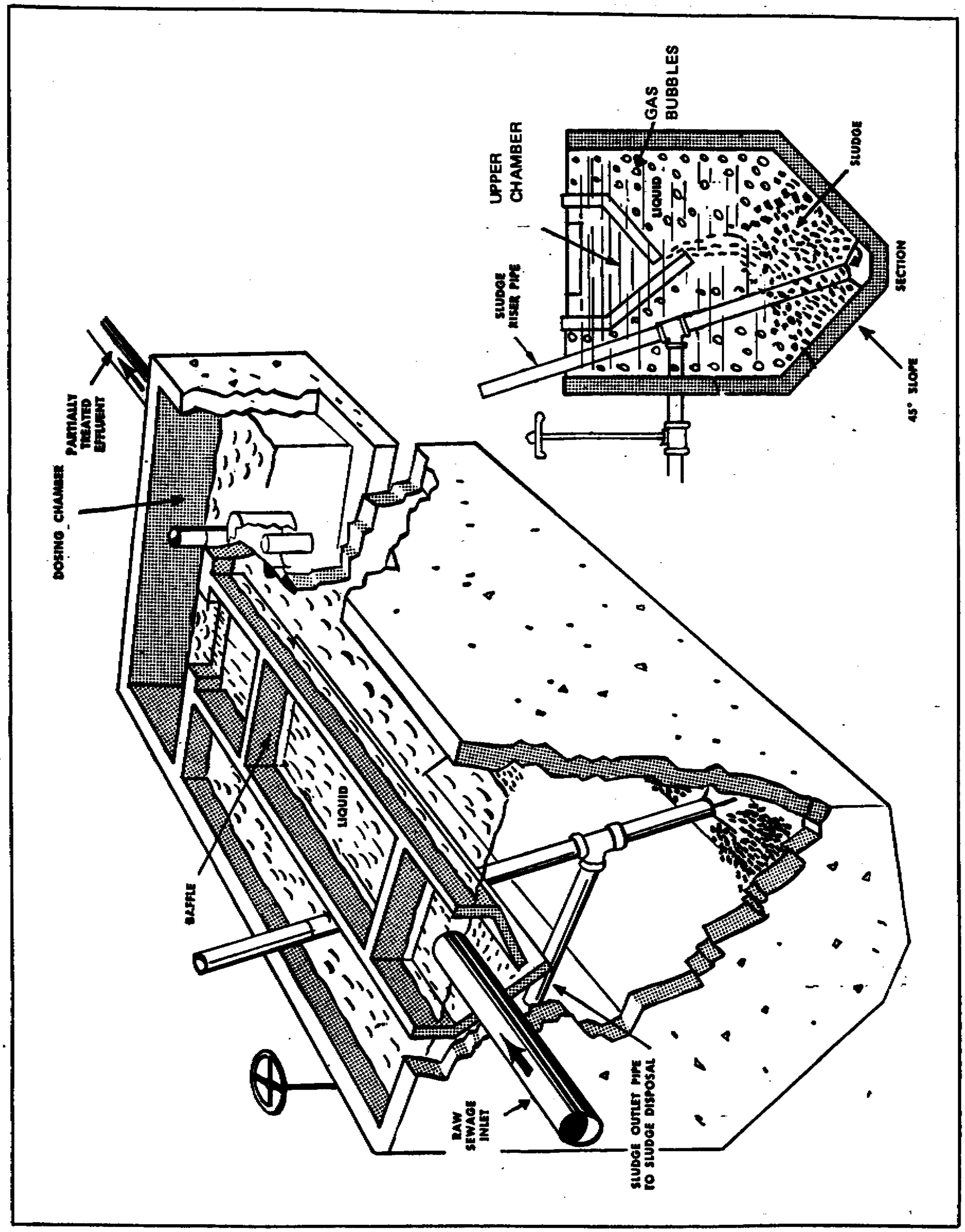


Figure 2-11. Imhoff tank.

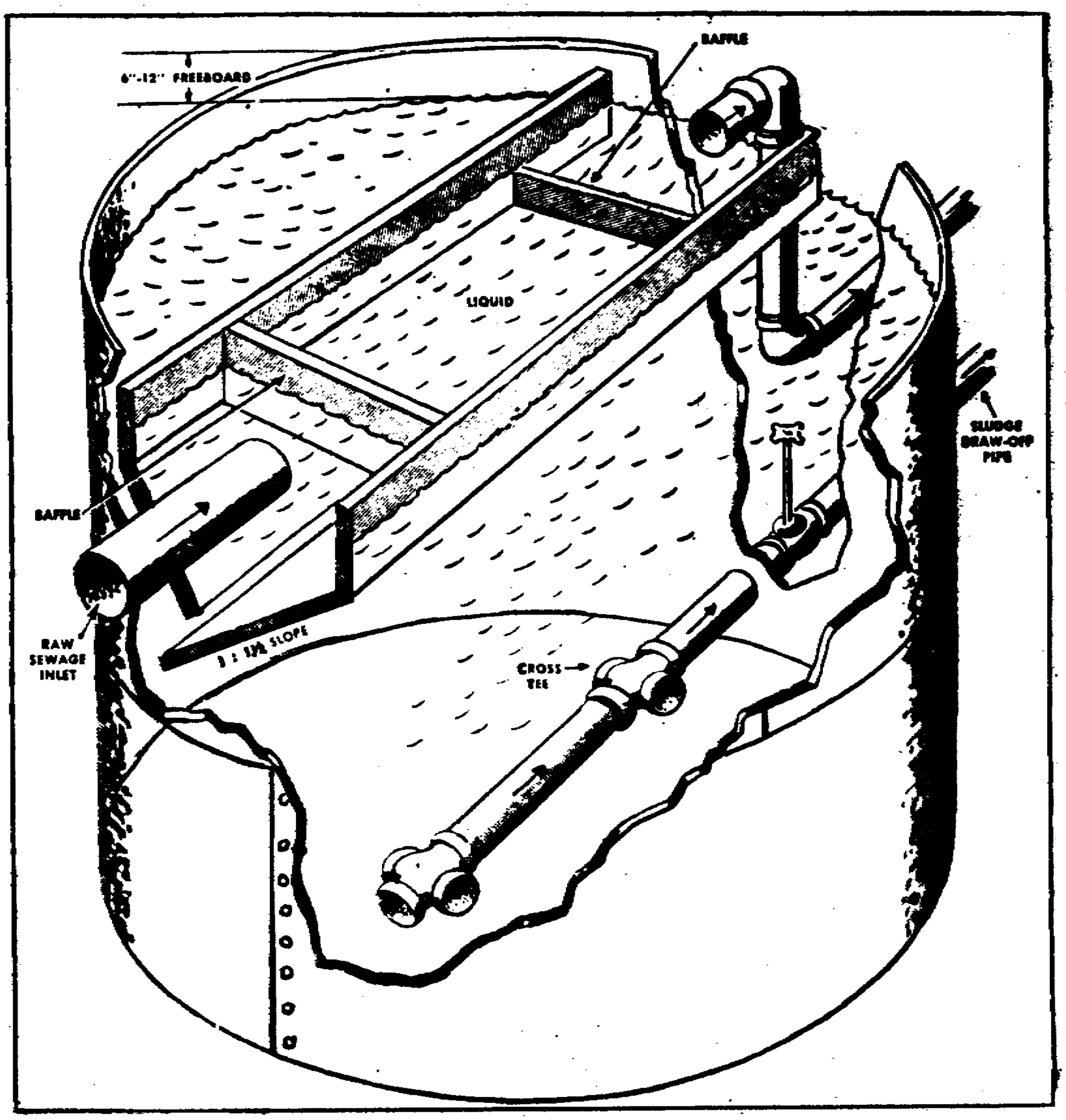


Figure 2-12. Circular Imhoff tank.

2-6. SLUDGE REMOVAL

a. **Methods of Removal.**

(1) Scum may be run to sludge digesters at the treatment plant, drained and hauled to the sanitary landfill or incinerator, or buried under at least two feet of earth. Another way of dealing with scum is to spray it with final effluent, causing it to settle with the sludge in the primary settling tank.

(2) Sludge is removed from primary settling tanks either by means of sludge pumps or by gravity. Figure 2-7 shows a tank with a gravity-flow sludge pipe, while Figures 2-8 and 2-9 illustrate tanks, which require pumps. Reciprocating pumps

or pumps with cutting edges in the suction inlet are most commonly used for primary sludge. The density of the sludge varies with the depth as it settles, that on the bottom being more dense than that which has just settled.

(3) Sludge from Imhoff tanks is permitted to remain for much longer periods of time since it undergoes complete digestion in the lower portion of the tank. Withdrawal is at a rate sufficient to remove only that portion of the sludge which is completely digested. The digested sludge from Imhoff tanks is normally pumped directly into sludge-drying beds (para 2-15b).

b. **Rate.** Proper sludge withdrawal is important to the efficiency of primary settling. If sludge is permitted to remain in a primary settling tank too long, septic conditions will result leading to the formation of gas and interference with natural sedimentation. On the other hand, the solids content of the sludge should be as high as possible for efficient digestion. Therefore, withdrawal must be stopped when the sludge becomes too thin. Sludge of proper consistency can be recognized from experience by correlating its appearance with sludge-solids test results. Primary sludge is normally removed from the settling tank 3 to 4 times each 24 hours.

Section II. SECONDARY WASTEWATER TREATMENT

2-7. GENERAL

Secondary wastewater treatment is performed to remove pollution from wastewater by changing dissolved and colloidal solids to settleable sludge through biological processes and then removing the sludge. Before the treatment processes are discussed, two biochemical *decomposition* terms and processes need clarification.

a. **Aerobic.** Aerobic decomposition is a relatively rapid process with stabilization being achieved in a matter of hours. In this process, bacteria decomposes and decays organic material in an oxygenated ("free" or dissolved oxygen present), aquatic environment. Aerobic bacteria live and reproduce only in an environment containing oxygen, which is needed for their respiration (breathing). This process is different than in anaerobic decomposition. In this process, oxygen that is combined chemically, such as in water (H_2O) or in sulfate (SO_4), cannot be used for the bacteria to breathe. The oxygen must be atmospheric or *dissolved* in water. As bacteria decomposes organic matter, enzymes formed as by-products of this biological action cause a limited chemical action on inorganic and organic compounds, both in suspension and in solution. The residual material from this biochemical action is relatively stable and will settle out readily in secondary settling tanks. As long as sufficient free oxygen is present to support the aerobic bacteria, aerobic decomposition continues. The reaction results are relatively odorless, with the principal gaseous by-product being carbon dioxide. If the supply of oxygen becomes insufficient and the oxygen demand has not been satisfied, anaerobic decomposition begins to occur.

b. **Anaerobic.** In this aquatic environment, "free" or dissolved oxygen is *not* present in the wastewater to supply bacteria the oxygen to breathe. The bacteria must break down chemical compounds that contain oxygen to survive. The decomposition and decay of organic material or digestion of the sludge by bacteria is the anaerobic process. Highly putrescible solids in the sludge are reduced in volume and character to relatively inert matter. *Ammonia*, *hydrogen sulfide*, and *methane* are liberated in the process. *Carbon dioxide* is also liberated, but in lesser amounts. Anaerobic decomposition is invariably foul smelling and is referred to as "septic." It is a slow process which may require weeks or months for complete stabilization.

2-8. BIOCHEMICAL AND CHEMICAL PROCESSES/OXIDATION

a. **Chemical Oxidation.** Besides biological oxidation processes taking place, there is a chemical oxidation process that is initiated at various stages in the treatment of wastewater. The biological aerobic and anaerobic terms were explained previously. Chemical oxidation is now explained.

(1) Oxidation process. Oxidation is the addition of oxygen to something or when one chemical is stripped of unit electrical charge (electrons) by another chemical due to the difference in their abilities to attract and hold this charge in tertiary wastewater treatment. In the treatment of wastewater, organic matter is oxidized to more stable substances. In this particular case, prior to disposing of the sediment/sludge, an "oxidizing agent" (chlorine) is added to strip or to remove the ammonia, reduce the concentration of residual organics, and reduce the bacterial and viral content of wastewaters.

(2) Chlorination. Chlorination is a form of oxidation which has been found to be operationally dependable in the removal of ammonia nitrogen. Once the undesirable water-carried material has been oxidized, it has a physical and chemical state which allows it to be removed from the water more readily. Oxidation of the organic material in wastewater with chlorine has been found to be enhanced by exposure to sunlight. The sunlight enhances the completion of the desired chemical reaction. When these occur, the material is disinfected. The amount of chlorine needed to oxidize the material is called *chlorine demand*. The amount of chlorine needed or left to keep the material disinfected is called *chlorine residual* (see table 2-1).

(3) Ozonization. Another type of chemical oxidation process is ozonization. Ozone is a form of oxygen found naturally in the earth's atmosphere. It can be produced industrially and sprayed into water to serve as a deodorant, dechlorant, and disinfectant. Ozone is toxic to organisms, which accounts for its disinfectant ability. Currently, however, this type of treatment is very expensive. (Chlorine is used more often to disinfect waste, but it, too, is expensive.)

Type of Treatment	Normal Range of Doses (mg/l)
Primary	3 -- 40
Trickling Filter	3 -- 15
Activated Sludge	2 -- 9
Sand Filter	1 -- 6

Table 2-1. Chlorine doses for different types of treatment plant effluents.

b. **Trickling Filter Unit.**

(1) Construction and use. A trickling filter of one kind or another is the most common secondary treatment unit at Army wastewater plants (see Figure 2-13). The filter medium is a bed of broken stone or slag 3 to 8 feet deep. Its holding structure is usually concrete, although it may be brick, masonry, or wood. The filter has a distribution system for spreading the wastewater uniformly and an underdrain system to remove filter effluent and circulate air through the filter. The underdrain system usually has a sloping channeled floor with slotted or open-joint vitrified-clay half tiles or blocks directly supporting the filter medium (see Figure 2-14). Wood-grid underdrains are also used.

(2) Filtration process. The action of the trickling filter is not mechanical or physical but is truly biochemical. The surfaces of the stones become coated with a gelatinous growth or *zoogleal film* (more commonly known as the *slime* layer). This layer of slime consists of bacteria, algae, fungi, and filth. It serves as a reservoir for an enormous volume of wastewater and keeps the wastewater in intimate contact with air and aerobic bacteria as it passes through the filter. Most of the filter consists of bacteria, which decomposes most of the organic waste into nitrates and is used as fuel. Protozoa feed on the bacteria, including the coliform bacteria Escherichia coli (E. coli). The bacteria content of the wastewater is thereby reduced by 50 to 70 percent as the wastewater passes through an efficient trickling filter bed. Fungi, although it treats the waste, is not as functional. Algae, which grow on top of the filter, do a limited amount of treatment. The waste flows over and partly through the slime. Colloidal, dissolved, and suspended organic matter passes to the underdrains and is converted into nitrates and used as fuel or food. For the filter to work, it must have enough oxygen. The oxygen is received from the wastewater and the air that circulates through the spaces between the media slime. These spaces or channels must be kept open to supply oxygen (rapid oxidation) to the slime and allow the waste to trickle through the filter. While the outside part of the biological slime is aerobic, there is a dark gray or black layer next to the media that is anaerobic. This layer occurs because the slime becomes thick enough to

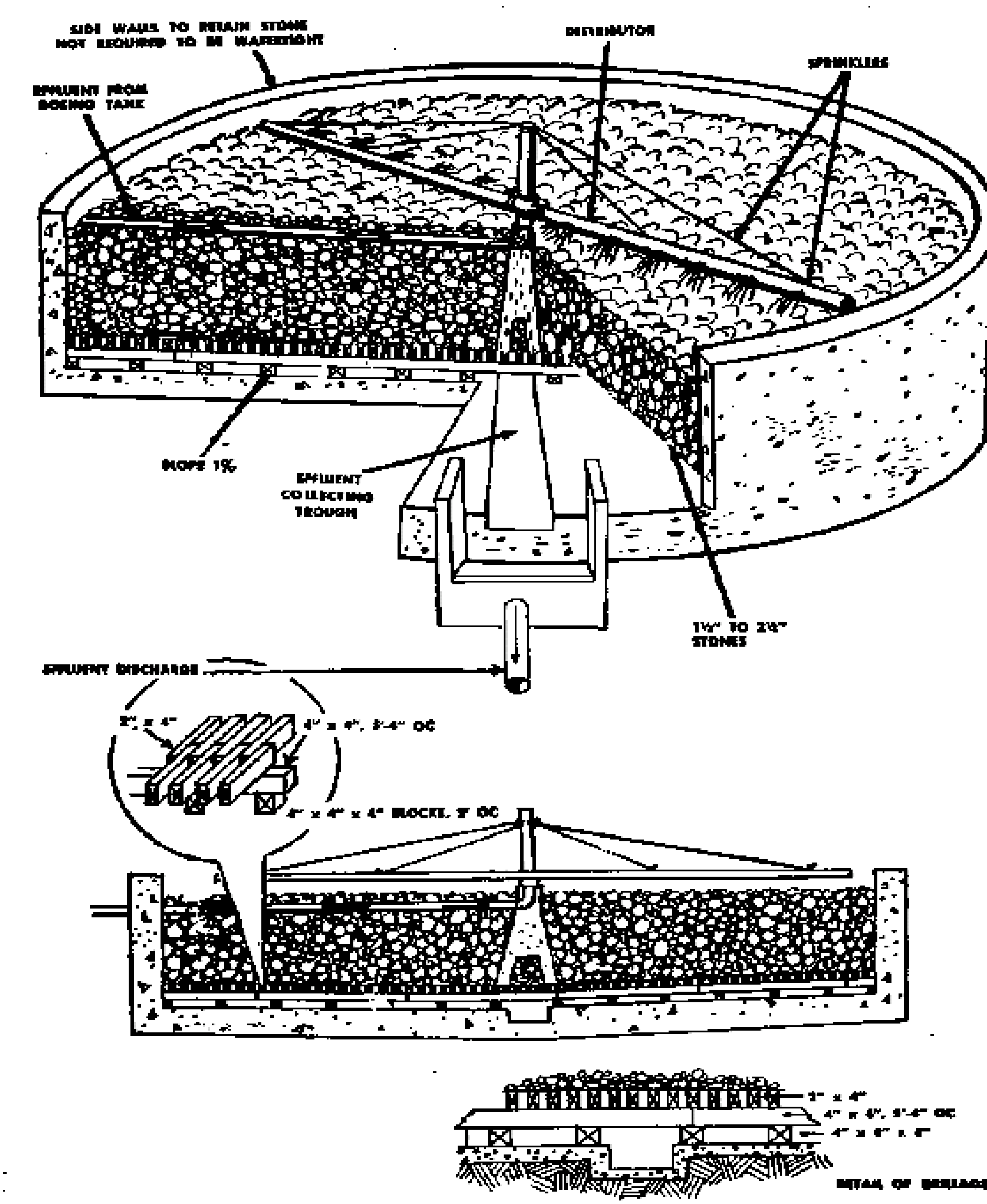


Figure 2-13. Trickling filter, schematic drawing.
(Note rotary distributor stone size, sloping floor, and wooden grillage.)

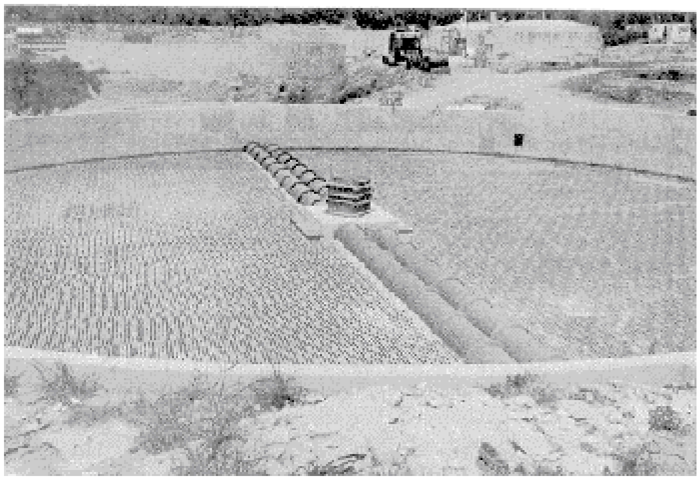


Figure 2-14. Trickling filter under construction.

use up all of the dissolved oxygen before it reaches the inner (anaerobic) layer. The anaerobic layer does not cling tightly to the media, so, when it gets thick, its outer portions die, break loose, and allow patches of slime to slough off the media. The amount of sloughing on a filter depends on the reactions taking place on the filter and upon certain conditions (the quality of the applied wastewater; rate and continuity of application; air supply; temperature; changes in the season, more so in the spring and fall; and other factors). The slime layer sloughs off from the filter (again, more so in the spring and fall) and is removed in the secondary clarifier. This forms a sludge which is called the trickling filter humus. The trickling filter removes solids by biological action (or a better name, "biological oxidation bed"), not by filtration. The sludge is fairly stable, but if it is not removed from the filter effluent by sedimentation, it may form objectionable sludge banks in the receiving stream. Therefore, a trickling filter is always followed by a settling tank where the slime is removed by sedimentation. These reactions differ in the two general types of filters (the standard low-capacity filter and the high-capacity filter) discussed a little later.

(a) Biological action. In deep, well-ventilated standard filters, two zones of activity are apparent. Organisms in the top of the filter break down proteins and amino acids into ammonia and simpler sulfur compounds and decompose carbohydrates to acids. At the lower levels, organisms oxidize ammonia and sulfur compounds to nitrites, stable nitrates, and sulfates.

(b) Unloading. A relatively thick growth develops in the standard filter during normal operation until a temperature change or flow of influent through the bed causes a large portion to slough off. This slough, usually occurring in the fall and spring, makes the filter effluent quite turbid and frequently contains large masses of worms normally present in the filter. These solids are removed in the final settling tank.

(3) <u>Types of trickling filters</u>. Trickling filters need food, oxygen, and biological forms to function and are labeled in different classes according to their amount of food (BOD) and flow. The four basic trickling filters are the roughing,

standard, high-capacity, and super-high-capacity filters. The standard and high-capacity filters are mentioned below.

(a) Standard (low-capacity) filters. These filters are usually rock media and with depths varying from 6 to 8 feet. They are a one-time filter with no recirculation and normally have high BOD removal (80 to 90 percent). Intermittent dosing is done by means of either fixed nozzles or a rotary distribution mechanism (see Figure 2-15).

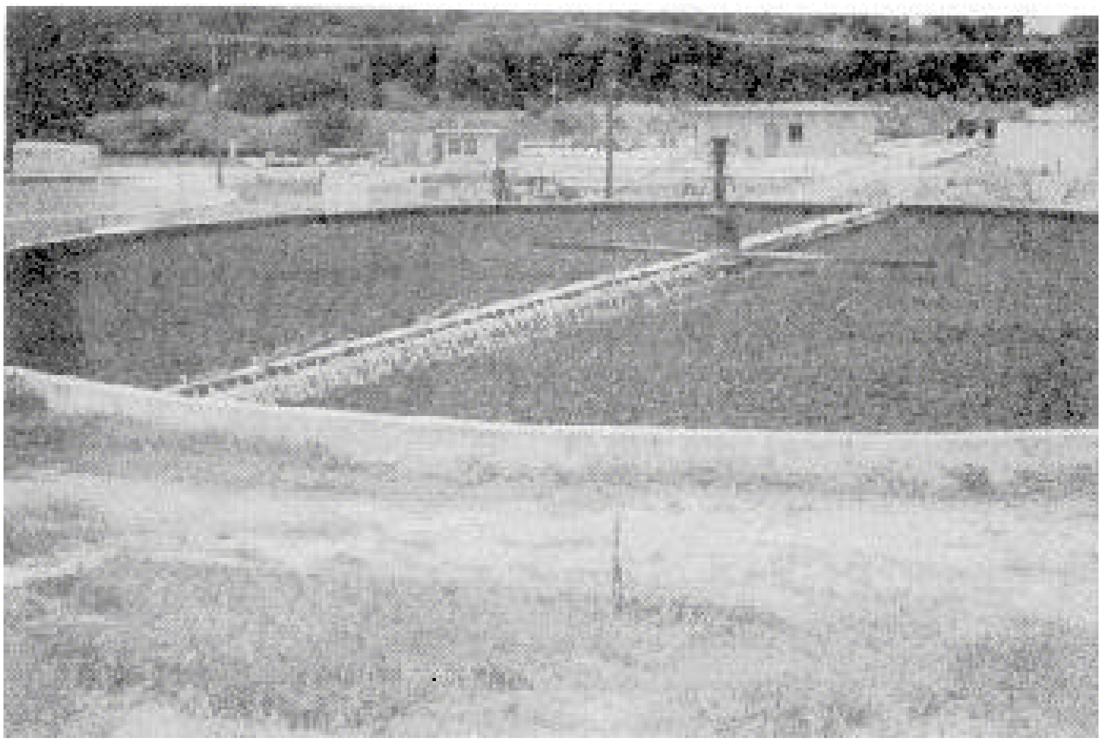


Figure 2-15. Trickling filter with rotary distributor.

(b) High-capacity trickling filters. High-capacity filter beds are made of rock media and vary from 3 to 8 feet in depth. The rocks serving as filter media vary in size from 3 to 4 1/2 inches, which is generally larger than those of a standard filter, thus allowing a great wastewater flow. Continuous dosing is usually by means of rotating distributors, although a few filters with special fixed nozzles have been constructed at Army posts. The underdrain system usually is designed to flow only one-third full under maximum operating conditions to ensure adequate ventilation. Recirculation almost always occurs.

1 High-capacity versus low-capacity filtration. The high-capacity filter has a continuous high-rate application that is well distributed over the bed surface. The high rate is assured by recertifying wastewater already passed through the filter, either continuously or during low flow (see Figure 2-16A and B). The heavy flow of wastewater over the biological growth produces continuous sloughing instead of the

periodic sloughing seen in the standard filter. Since solids are not retained in the high-capacity filter for long periods as they are in the standard filter, they are less stable and continue to exert a considerable oxygen demand in settling tanks receiving filter effluent. Likewise, the solids continue wastewater clarification and BOD removal in the settling tanks as long as aerobic conditions are maintained. The settling tanks, including primary tanks if filter effluent is returned through them, are integral parts of high-capacity filter treatment.

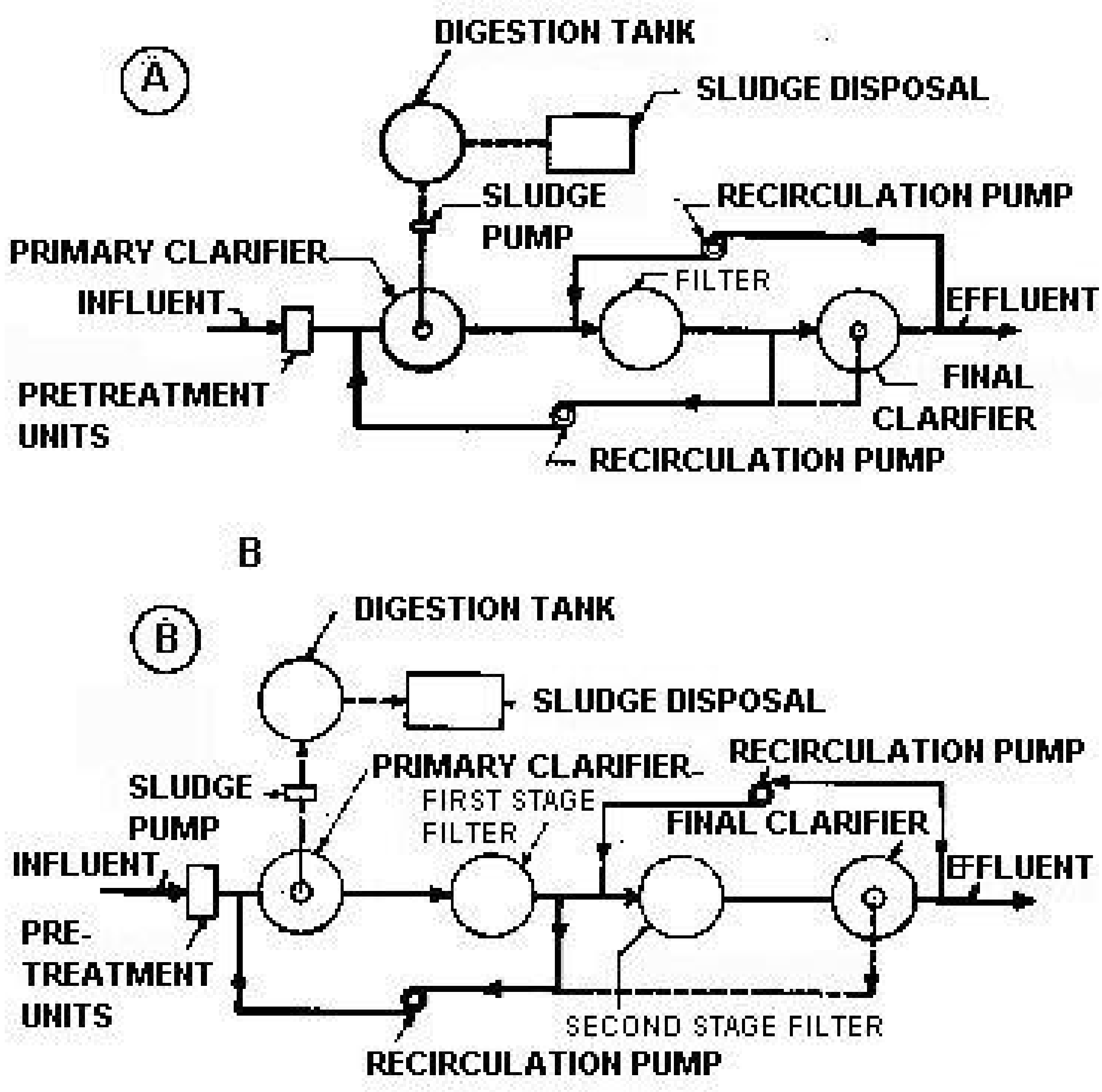


Figure 2-16. Wastewater flow diagram at plants using high-capacity filters. (A) single stage. (B) two-stage filters.

2 Combined high-and low-capacity filters. Excellent results are obtained by using a high-capacity or roughing filter followed by an intermediate-settling tank, a low-capacity filter, and a final-settling tank (see Figure 2-16B). Continuous flow is maintained by recirculation.

(4) Maintenance operations and control of health hazards.

(a) Distributors and spray nozzles. Orifices should be cleaned daily. All scum and growths should be removed from rotary distributors weekly. Wastewater from the distribution apparatus should not be sprayed on the ground around the filter. Shields on distribution arms and adjustments of spray velocity are appropriate safeguards.

(b) Filter surface. The filter surface should be kept free of leaves; removal of nearby trees may be necessary. In winter, the filter surface-face should be kept sufficiently free of snow to permit rotation of distributor arms. If small particles of rock or sand are washed out of the filter, they should be removed from the collection channels manually to prevent their discharge to settling tanks. If this material reaches the digester, it may plug sludge lines and reduce digester capacity . At some installations, a small grit chamber is installed to remove these particles.

(c) Ponding. Ponding of filters may occur if prolific fungus growths fill the voids between the rocks to the extent that water passage through the filter is inadequate. Such growths may develop if the filter stone is too small or has broken up, if the filter is heavily loaded or poorly ventilated, or if wastes containing large amounts of carbohydrates are treated. Excessive grease or nofiltrable residue may plug the filter. Ponding may be reduced by the following methods.

1 Flushing the filter surface with a fire hose.

2 Raking or forking the surface.

3 Stopping the distributor over the affected area and allowing the continuous flow to wash down the growth.

4 Punching holes through the top layer of the filter rock with an iron bar or pick, but not with heavy equipment which would crush the underdrains or otherwise damage the filter.

5 Adding heavy applications of chlorine or chlorinated lime up to 5 ppm residual to filter influent for 2 to 4 hours at weekly intervals, preferably at night when the flow and chlorine demand are low. This is after a residual up to 5 ppm applied 3 or 5 hours daily for several days starts the solids sloughing from the stone. Filter flies can be controlled somewhat by chlorinating to a residual of 0.5 to 1.0 ppm for several hours at 2-week intervals.

CAUTION: Avoid decreasing filter efficiency by destroying the bacterial growth by chlorination.

6 Flooding the filter, if possible.

7 Allowing the growth to dry by taking the filter out of service for 12 to 48 hours if other adequate filter units are available to continue treatment of the wastewater generated at the installation.

8 Removing stone and replacing it with a large size if all other methods fail.

(d) Insects.

1 Filter fly. Several species of flies frequently infest the standard filter. A fly which is particularly prevalent is commonly called the filter fly. This fly is a small, mothlike insect belonging to the same family as the *Phlebotomus* fly. Heavy infestation with fly larvae comes with thick zoogleal product growth on filter stones when the air temperature is high. Filter fly larvae assist in the biological action of the filter; however, a heavy infestation may clog the filter. Also, the fly, which is small enough to pass through ordinary window screens, is a great source of annoyance to plant operating personnel and nearby residents because it is attracted to human eyes, nostrils, mouths, and ears. Breeding in filters is minimized considerably by continuous application of influent at a high rate and by keeping stone and wall surfaces constantly wet. Filter flies prefer alternate wet and dry environments. Pupae and larvae developing under such conditions are continuously washed to the final settling tank where they may have to be skimmed from the surface. *Psychoda* flies may become a nuisance particularly on standard filters operated by intermittent dosage. Serious fly nuisance may be controlled by: (1) reducing food supply and film development, thereby removing excessive filter growths ; (2) hosing the inside of the filter walls vigorously; (3) flooding the filter for about 12 hours every 2 weeks; or (4) using chlorine or such other chemicals as prescribed by higher technical authority.

2 Water springtail. The water springtail--a small wingless, biting insect of the order Collembola--may occur in trickling filters. This insect feeds upon the organic growths in the exposed bed surface and helps keep it clean.

c. **Filtration Unit.**

(1) Material. The filter bed (see Figure 2-17) consists preferably of clean quartz sand ranging in size from 0.20 to 0.36 millimeters (mm). Sand grains smaller than 0.20 mm permit filtering at a lower rate and clogging of the beds; sand grains larger than 0.36 mm permit a high filtration rate, but allow fine organic material to penetrate deep into the bed. Filters are most economically constructed if natural sand deposits can be used, with retaining walls being constructed from topsoil. Underdrains, if required, are usually of vitrified tile 4 to 6 inches in diameter laid in lines 3 to 4 feet

apart and 3 to 4 feet below the surface of the bed with a 3/8 inch space between each tile in a line. The drain is surrounded with 2 or 3 layers of different-sized gravel to prevent the passage of sand into the lines. The lines usually lead through a single outlet to a water course.

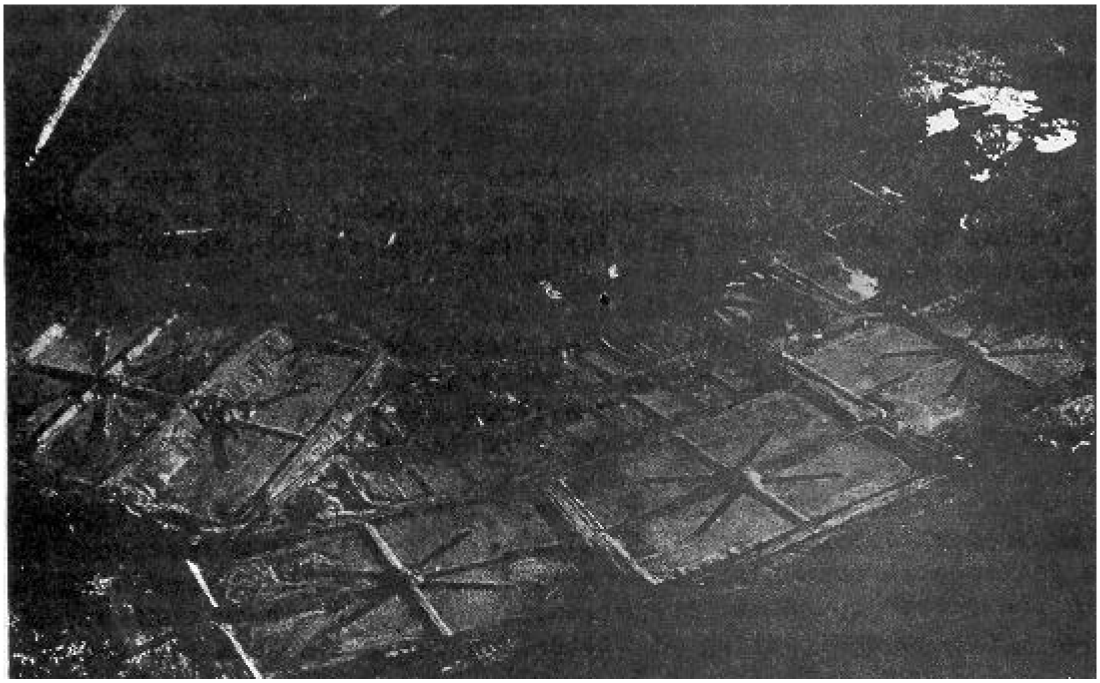


Figure 2-17. Aerial view of wastewater treatment plant with intermittent sand filters. (In each set of four beds, distribution troughs for dosing radiate from a central diversion box.)

(2) Filtration process. Wastewater is filtered through sand as a secondary treatment following primary settling or for further treatment following other secondary processes. Discharge to natural sand deposits is sometimes used as a method of disposal whereby wastewater passes into the ground water and there is no surface effluent. Sand filters with underdrains usually produce an effluent that is clear, sparkling, low in nonfiltrable residues and BOD, and highly nitrified. The filter removes nonfiltrable residues mechanically by straining and oxidizes organic matter by action of bacterial films on the sand grains.

(a) Dosing. The size of individual doses, rate of application, and frequency of dosing vary considerably. The rate must be high enough to cover the entire bed quickly to a 3-inch average depth. Dosage varies from one dose every other day to three daily. To permit thorough bed aeration, the bed must drain thoroughly and the flow in the underdrains from the filter must be very low before the bed is used again.

(b) Adding ridges/mounds. In cold climates, freezing may seriously interfere with sand-filter operation. To avoid such difficulty, the bed may be furrowed every 3 feet into ridges about 10 inches high; ice is then supported by the ridges. A method which simplifies subsequent cleaning is leaving mounds of material from the last fall cleaning about 1 foot high and 4 to 8 feet apart to support the ice. The mounds are completely removed for spring cleaning.

(3) Maintenance. When pools of wastewater remain on a filter several hours after dosing, the filter should be taken out of service until dry and then cleaned. When settled wastewater is applied, a mat that dries, cracks, and curls forms on the surface. The mat is readily removed with forks or rakes. When the effluent from secondary treatment is applied to sand filters, a mat may form slowly or not at all and clogging may take place between the top sand grains. Cleaning is then necessary at less frequent intervals. About 1/2 inch of the top sand must be removed with shovels or hand scraper when required.

(a) Remove mat. Hand removal is customary, but at plants without underdrains, tractor-drawn scoop-type scrapers may be used. Heavy equipment cannot be used on beds having underdrains because the tile will be crushed.

(b) Level surface. After the surface has been cleaned, it should be loosened with a garden rake and leveled to grade. Harrowing a sand filter should be resorted to only for deep clogging because harrowing fouls the sand to greater depths.

(c) Add sand. New sand must be added periodically to maintain proper sand depth over the underdrain. For filters built in natural sand deposits of considerable depth without underdrains, sand need rarely be added except for small quantities required for leveling.

(d) Avoid ponding. Sand filters must not be allowed to pond or to be used as lagoons after clogging except in extreme emergency because solids continue to accumulate on the surface. It then becomes difficult to restore the filter to normal operation. Control of grease content, plus frequent cleaning and resting of filters, usually prevents ponding.

d. **Activated Sludge Unit.**

(1) General. The activated sludge system is a biological unit used for secondary treatment. This system or process removes dissolved and suspended solids from wastewater, changing it to more stable substances for removal later in a final settling basin or clarifier. This process is accomplished by rapid oxidation of organic matter by aerobic microorganisms. When wastewater is agitated continuously in the presence of oxygen, the nonfiltrable residue agglutinates or flocculates. This floc is called *activated sludge*.

(2) Properties of activated sludge. Good quality activated sludge is usually brown in color, is granular in appearance with sharply defined edges, and has a slight musty odor. It is a biologically active material containing numerous microorganisms and a mixture of organic solids in various stages of decomposition. Some materials are

consumed by the microorganisms; others are thought to be converted by enzyme action from objectionable matter to stable substances. Activated sludge absorbs dissolved organic material, including ammonia. High quality activated sludge settles rapidly, leaving a clear, odorless, stable liquid above.

(3) Principles of the process.

(a) After receiving primary settling, wastewater is mixed with activated sludge to form a mixed liquor. The mixed liquor then receives prolonged aeration in an aeration tank and is conveyed to the final settling tank from which a clear, effluent liquid is usually discharged without further treatment except chlorination. The sludge collected at the tank's bottom is returned, all or in part, to the influent end of the aeration tank. It is mixed with incoming settled wastewater to continue the purification process. Excess sludge is usually pumped to the plant influent and is resettled with the primary sludge to concentrate it. Figure 2-18 illustrates graphically the flow in an activated sludge plant.

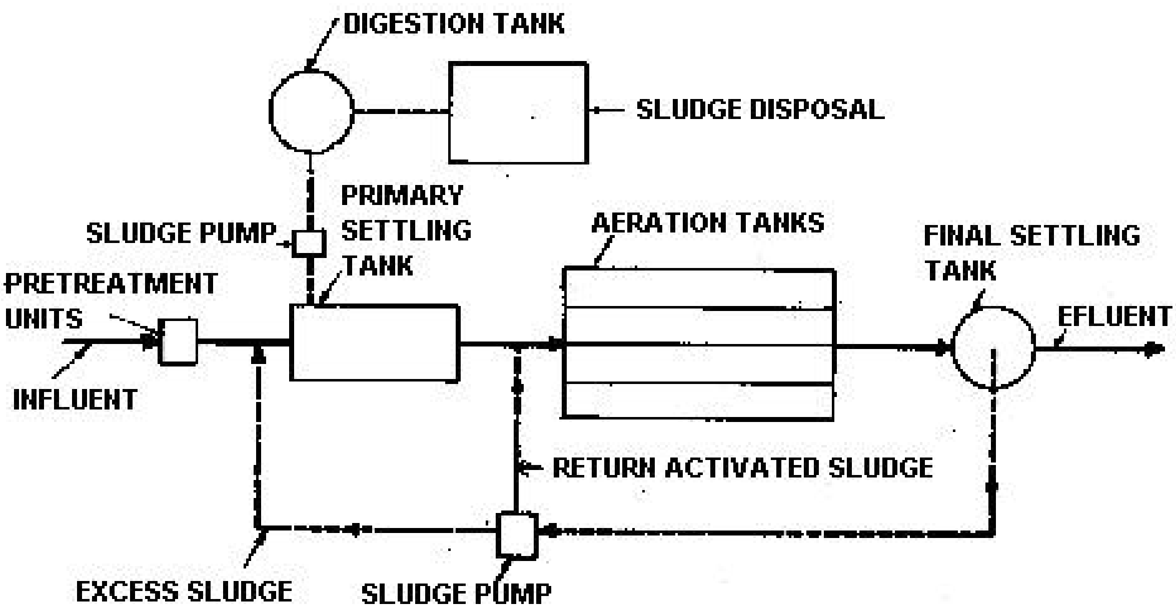


Figure 2-18. Flow diagram of an activated sludge plant.

(b) Approximately 80 to 85 percent of wastewater treatment occurs during the first hour of aeration. Aeration not only assists the microorganisms in getting oxygen, but also causes contact of activated sludge with the wastewater solids to create floc. Floc becomes heavy and settles. During the rest of the period, sludge is regenerated, organic matter stabilized, and sludge conditioned for further activity. The sludge's capacity for taking in organic matter is limited and regeneration is necessary before an additional load is applied. Activated sludge requires oxygen at a definite, measurable rate. It absorbs oxygen from the water as rapidly with only a few parts per million in solution as when the water is almost saturated. The activated sludge process also requires nutrients in the form of carbon, nitrogen, and phosphorous. These nutrients help the microorganisms grow.

(c) Bulking of activated sludge caused by excessive growths of hairlike bacteria can usually be corrected and controlled by applying chlorine to the return sludge. Overchlorination upsets the process and must be avoided. When bulking has been continuous, constant application of small amounts of chlorine to the return sludge may maintain a low sludge index; partial prechlorination of the raw wastewater may have the same effect.

(d) Volume of activated sludge returned from final settling tanks to aeration tanks normally ranges from 20 to 40 percent of the raw wastewater flow. A high rate of return reduces aerator detention time but keeps sludge fresh and may return needed dissolved oxygen to the aerator inlet. A low rate of return increases aerator detention time; it is feasible when the sludge has a low rate of oxygen utilization and does not readily become septic. A high return sludge concentration is obtained with low return rate.

(4) Types of aerators. Three types of aerators in common use in activated sludge treatment plants are different air, contact aeration, and mechanical.

(a) Diffused air type. These tanks are rectangular in shape and allow compressed air to be admitted through diffuser plates or tubes. About 95 to 98 percent of the air keeps the contents in motion, the rest is for oxidation. Figure 2-19 pictures an empty tank equipped with diffuser tubes.

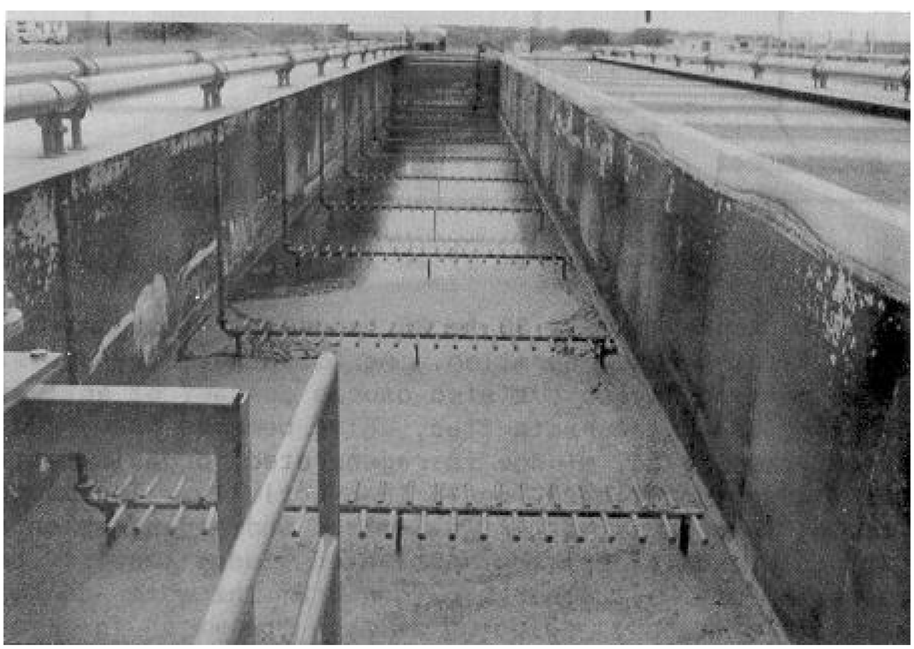


Figure 2-19. Aeration tank with diffuser tubes.

(b) Contact aerator. The contact aerator (see Figure 2-20) consists of a contact bed made up of cement-asbestos plates on which a biological film develops. An aerobic condition is maintained by blowing air through the contact section from perforated pipes mounted below the contact plates.

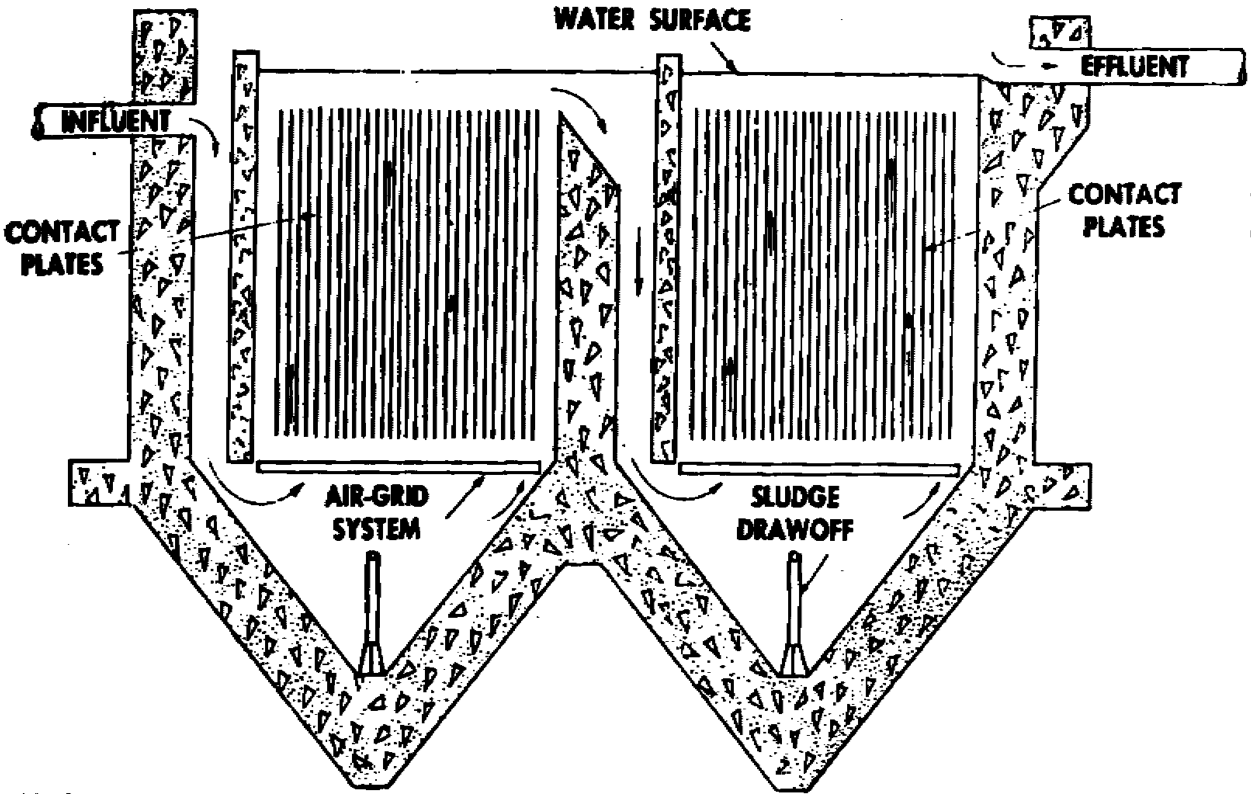


Figure 2-20. Contact aerator.

(c) Mechanical type. Mechanical aerators use impellers, revolving disks, or brushes for spraying wastewater into the air or pulling air down into the wastewater. Figure 2-21 illustrates equipment for pulling wastewater up through a cone-shaped draft tube from the bottom of the tank and spraying it into the air by means of an impeller. Air mixed with the spray is diverted downward into the tank by the diffuser cone. This method of aeration is used in small plants. If circular tanks are used, internal wall baffles will be provided to prevent potential vortexing (liquid vacuum in the center) problems.

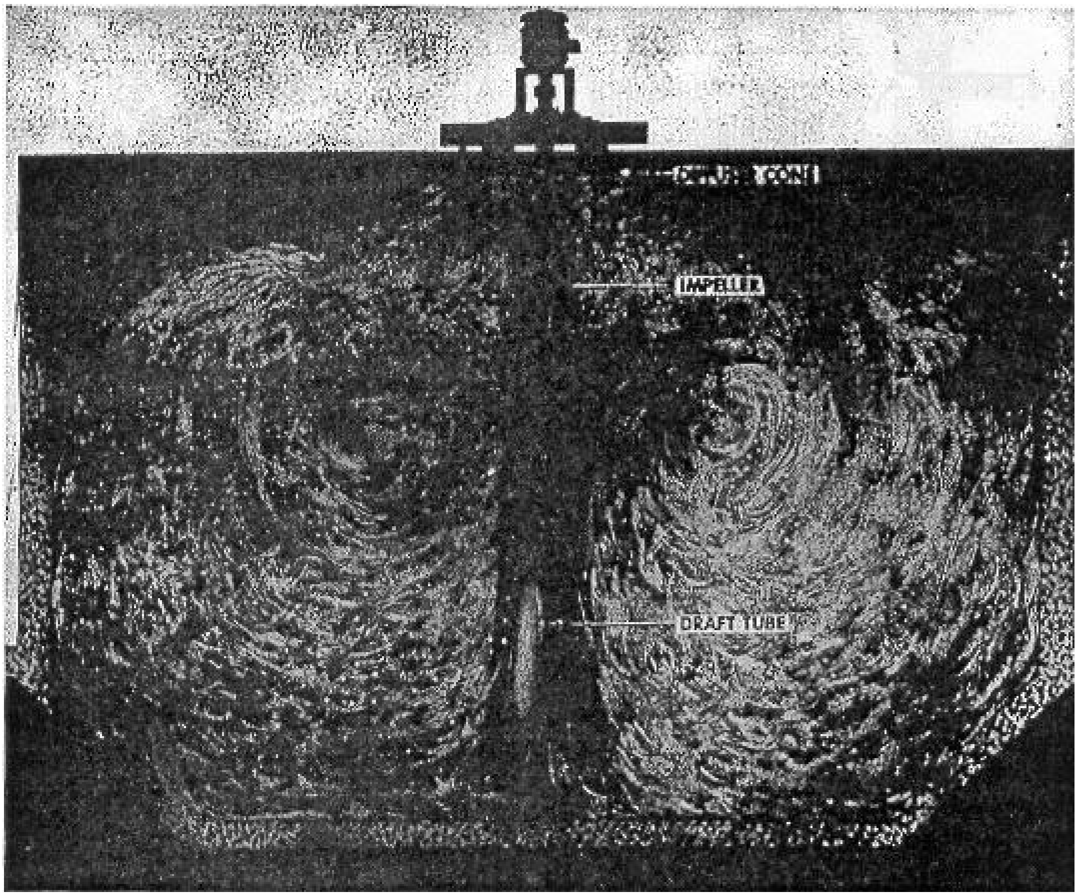


Figure 2-21. Mechanical aeration tank.

(5) Variations. A number of possibilities exist for varying the activated sludge process. Three will be mentioned here.

(a) Step aeration. This process is designed to offset the effects of fluctuations in influent and sludge quality. Instead of introducing the influent at one point, as in the conventional unit, it is introduced uniformly at a number of points along the aeration tank as shown in Figure 2-22. Thus, the large aeration basin is actually broken down into smaller basins. The use of this modification allows for absorption of organics at more than one point in the tank. Therefore, there is accelerated growth and oxidation spread out over the basin. Also, by distributing the organic load over the entire tank, it is possible to decrease the detention time in the tank and to maintain a lower solids concentration in the mixed liquor. BOD reduction lies between 85 percent and 95 percent. To implement this type of upgrading, it is necessary to modify influent piping, renovate the air system, and expand the sludge recycle capacity. Primary and secondary clarifier capacity must be checked and increased to handle the higher loads.

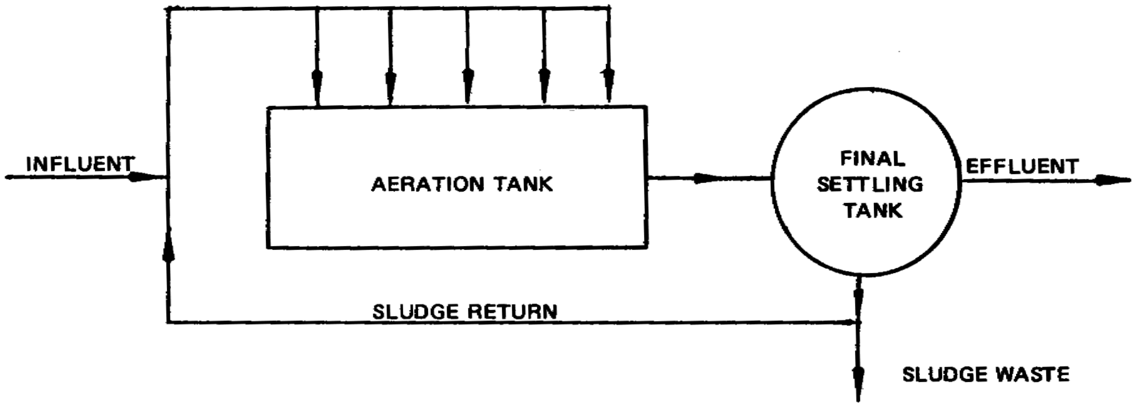


Figure 2-22. Step aeration.

(b) Two-stage treatment. One aeration and settling tank (first stage) is followed by second identical set (second stage). Sludge is either recycled or wasted within each stage, or excess sludge from one stage is recycled to the other. This procedure offers flexibility in exploiting the quality of both sludges. Figure 2-23 illustrates the two-stage process.

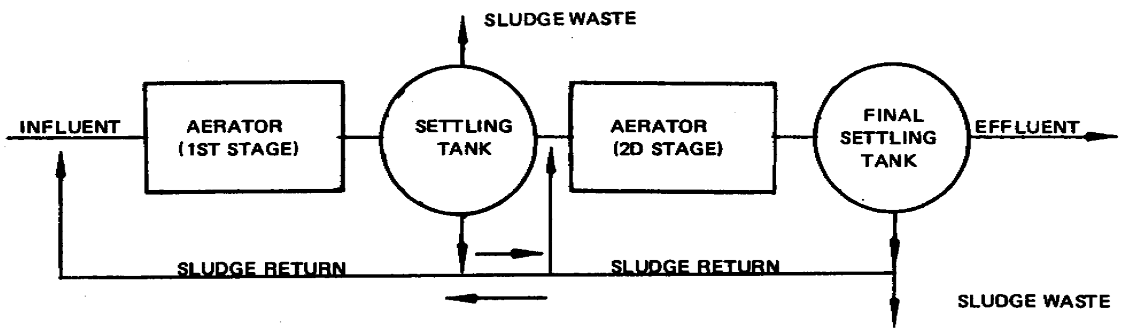


Figure 2-23. Two-stage aeration.

(c) Contact stabilization. An overloaded conventional activated sludge plant is upgraded by converting the existing aeration tank to two separate tanks, one for stabilization of returned sludge and the second as the contact tank for the raw wastewater. Contact stabilization is normally accomplished in two stages, as shown in Figure 2-24. Detention time in the first stage is usually limited to 20-40 minutes. The organisms which develop on the contact plates (see Figure 2-20) are quite similar to those which make up the zoogleal film (*schmutzdecke*) in the trickling filter and identical with activated sludge produced by other types of aeration equipment. The settlement sludge is removed in a settling tank following first-stage aeration. The effluent flows into a second aerator, to which digester supernatant (see para 2-18) has been added as a nutrient for the further oxidation of soluble organics (see Figure 2-25). Normally, only the sludge from the second-stage unit is returned to the incoming wastewater influent.

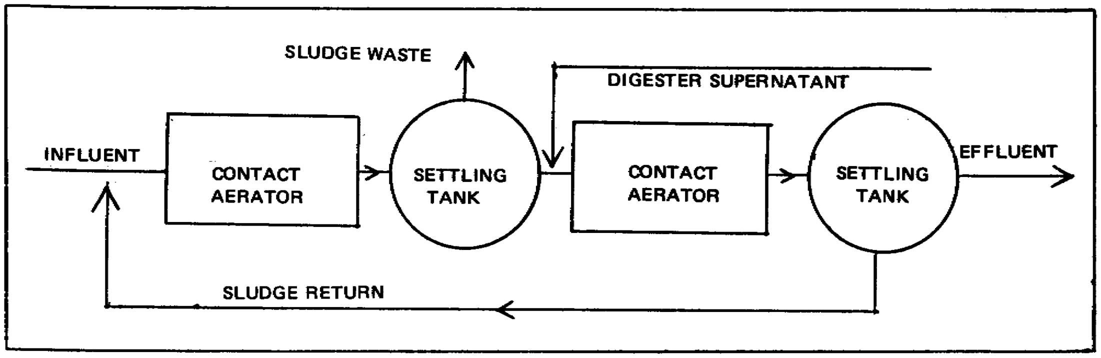


Figure 2-24. Contact stabilization.

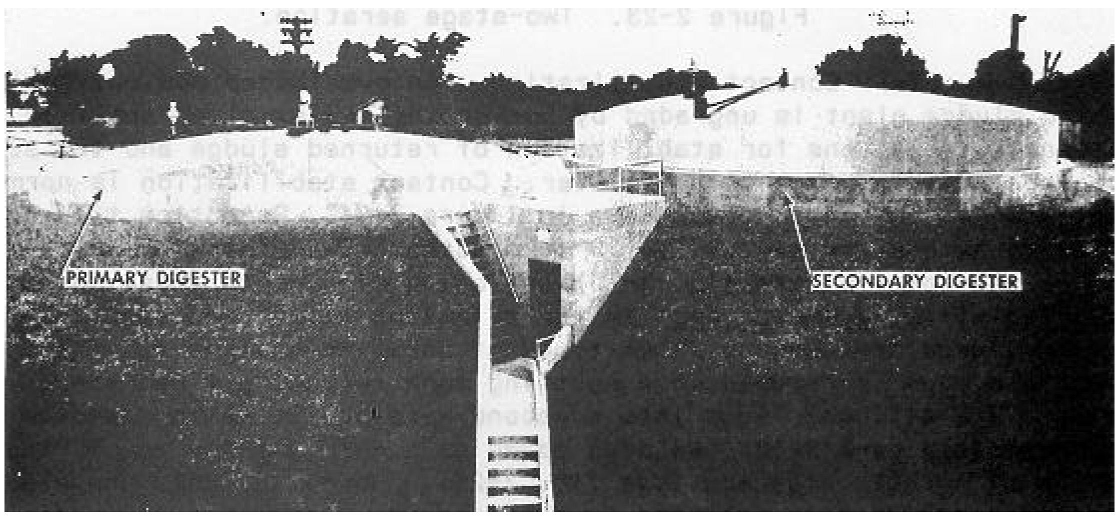


Figure 2-25. Digesters for two-stage digestion.
(Primary digester [left] has fixed cover; secondary digester [right] has gas-holder cover.)

2-9. SECONDARY SEDIMENTATION

a. **General.** Sedimentation or settling following biochemical processes is an essential part of secondary treatment of wastewater although it is primarily a *physical process*. The settling tanks and operating mechanisms are of the same or similar design as those used in primary sedimentation (see para 2-5c). The retention period is shorter than for primary sedimentation and the quantity of solids or sludge removed is usually much less. The sludge is usually transferred to digestion tanks along with sludge from primary sedimentation units (see para 2-6, see Figure 2-16).

b. **Sludge Removal.** Secondary sedimentation units do not require as much attention as primary units, but a regular cleaning and frequent removal of sludge is essential.

(1) Standard trickling filters. Sludge in sedimentation tanks following standard trickling filters must be removed often enough to prevent rising sludge. Once daily may be enough in cold weather if sludge is stable. Denitrification may occur in warm weather, causing release of nitrogen gas and rising sludge. Sludge removal every 3 hours may be necessary for control of rising sludge and during the filter sloughing period.

(2) High-capacity filters. Sludge in sedimentation tanks following high-capacity filters must be removed at least once each shift, or more frequently, as required. This sludge becomes septic much more rapidly than that from standard filters. At some installations, sludge can be removed continuously.

c. **Filter Effluent Recirculation.** The amount of recirculation for any particular filtration process (see Figure 2-16) depends upon a number of factors. Experience is necessary to determine the most effective method and rate of recirculation. The best guide is recirculation of filter effluent in a sufficient amount to provide 1 ppm minimum dissolved oxygen in the settling tank receiving recirculated effluent. Control samples are taken in the inside of the effluent weir of the filter ahead of the settling tank. Since several weeks are needed for the filter to adjust to the changes, each trial must be continued with appropriate tests for one month before any conclusions are made--unless, of course, failure becomes obvious.

Section III. TERTIARY WASTEWATER TREATMENT

2-10. CARBON ADSORPTION

a. **Columns.** Activated carbon is produced by chemically treating charred wood particles. It can be packed into vertical columns arranged in series or parallel and then placed so the wastewater to be treated flows through it. Depending on flow conditions, the carbon particles may float or remain stationary at the bottom of the columns. The flow may be induced by mechanical pressure or gravity acceleration. Series configurations achieve more complete organic removal and will be used when carbon absorption is required to remove 90 percent of the total plant organics. For lower levels of treatment, staggered parallel columns can produce a greater volumetric flow of passage while still maintaining removal efficiency.

b. **Backwashing.** The carbon media can be cleaned by a technique known as backwashing. This involves reversing the flow of water through the columns so that collected solids and nonfiltrable residues may be "blown" back through the columns to a position where they may be collected.

c. **Process Design.** Where practical, carbon column studies should be conducted on the waste to be treated to determine the process design. These studies should test the type of activated carbon that will be used in operating the full-scale plant.

(1) Pretreatment. Pretreatment will be provided as necessary to keep the nonfiltrable residue concentrations below 50 mg/l, unless the carbon bed is to be used as a filter also.

(2) Carbon size. The carbon will be 8 X 30 mesh granular carbon, unless carbon column studies show a different size to be more effective.

(3) Contact time. Contact time is the most important design factor affecting organics removal and should be determined empirically for the particular situation. Typical values range from 18 to 36 minutes.

(4) Hydraulic loadings. Hydraulic loadings from 2 to 10 gallons per minute/square feet (gpm/sq. ft.) are acceptable and effective in organics removal at this range. The main consideration is with head loss build-up. Gravity-flow systems are limited to hydraulic loadings less than 4 gpm/sq. ft.

(5) Carbon quantities and adsorption capacity. Carbon requirements range from 250 to 350 pounds of carbon per million gallons treated. The adsorption capacity of carbon is affected by several factors and should be determined experimentally for each particular wastewater to be treated. Factors that influence adsorption include surface area, nature of the material to be treated, pH, temperature, nature of carbon, and complexity of material to be absorbed.

d. **Considerations.** The effluent quality requirement will determine the required contact time, and this, in turn, will set the approximate total carbon volume. The hydraulic loading will determine the total cross-sectional area and total carbon bed depth. The total cross-sectional area can be divided into separate carbon beds in parallel and the total bed depth can be divided between beds in series. Vessel heights should provide for bed expansion of 50 percent. Contact tanks should have length-to-diameter ratios of between 0.75 to 2.0, with carbon depths usually greater than 10 feet. The tanks should be constructed of concrete or lined carbon steel. Typical coating materials range from a painted coal tar epoxy to laminated rubber linings. The carbon transport system must be designed to resist the abrasiveness of carbon slurry.

2-11. COAGULATION-SEDIMENTATION

a. **Pretreatment.** The wastewater is usually pretreated before undergoing this chemical and physical process. Skimming tanks are used to separate the wastewater from the lighter floating objects. Grease traps are used to trap large oily or greasy discharges. Wastewater is also preaerated before coagulation-sedimentation to improve treatability, provide grease separation and odor control, provide grit removal, cause flocculation, increase BOD removal, and promote uniform distribution of suspended (nonfiltrable) residues and floating residues. Once these pretreatment operations are complete, coagulation may be commenced.

b. **Design Considerations.** Surface area of tank and retention time are the two primary considerations in designing and operating a coagulation-sedimentation tank system. *Surface area* is the area of the tank liquid surface exposed to the atmosphere. This parameter allows for adequate chemical-solids interaction. *Detention time* is the amount of time a solid particle or unit volume of water will spend in the tank. This parameter also allows for the chemical-solids interaction to occur.

c**. Residues.** The settled residues collect on the bottom of the sedimentation tank because their density is greater than that of water. Depending upon the type of tank, mechanical collectors scrape the settled residues or pumps suck the sludge swells from the bottom into hoppers, which are then transported for ultimate disposal via land application, centrifuging, or ponding.

2-12. MEMBRANE PROCESSES

a. **Electrodialysis**. In this procedure, stacks of alternating positively and negatively charged membranes in single and multi-stage configurations constitute the semipermeable membrane. Different impurities are removed in different degrees according to the selectivity of the membrane.

(1) Pretreatment. Plugging of the membrane can be prevented by pretreatment with carbon adsorption or filtration. The water to be treated is held in large tanks, with the membranes serving as obstacles to flow. All correctly charged particles in the water are attracted to the membrane obstacle, but only certain ones are able to pass through. This allows for selective distribution of the particles and a cleaner water. Chlorine oxidation disinfects the matter.

(2) Efficiency factors. Factors such as air temperature, water temperature, water pH, and electrical power applied to the equipment determine the efficiency of this process.

b. **Reverse Osmosis.**

(1) Use of reverse osmosis. This process is used primarily to remove salt from sea water (desalination) for drinking or manufacturing purposes. Reverse osmosis operates at pressures of 500 to 1,500 pounds per square inch with hydraulic application rates of 3 to 50 gallons per day per square foot. The reverse osmosis membrane will reject from 90 to 99 percent of the total dissolved solids presented to it. Either process will remove 100 percent of the suspended solids. High temperature conditions allow for more water to be treated with this process.

(2) Equipment. Reverse osmosis equipment is usually designed as hollow-fiber, spiral-wound membrane, or as tubular units. Pressure can be applied to the high salt-strength water in the tubes. This forces the water present through the barrier membrane while trapping the salt and solids in the tubes.

2-13. ION EXCHANGE

a. **Types of Processes.** Ion exchange operations are either batch or continuous type. In the batch process, the reaction is confined to the contents of one vessel at a time. In the continuous type, there is a constant feed and a constant drain. In the batch process, the resin is stirred with the water to be treated until the equilibrium reaction is complete. Used resin is removed by settling. In the continuous process, the exchange material is placed in a bed or column and the water is passed through it.

b. **Resins.** The extent of removal of the ions in the water depends upon the chemical equilibrium state between the ions in the liquid phase and those in the solid resin material. Both natural and man-made ion-bearing resins are available. Regenerant and separate restorant chemicals are used to remove the undesirable inorganic ions and organic materials from the used resin in order to prepare the resin for reuse.

Section IV. SLUDGE

2-14. SLUDGE DIGESTION

a. **General.** For each milIion gallons of wastewater passing through a treatment plant, 5 to 10 thousand gallons of sludge are collected In the sedimentation units. This sludge is about 95 percent water and about 5 percent (50,000 ppm) highly putrescible organic matter. The sludge collected in settling tanks and not stabilized by return to the influent is treated in a separate sludge digester. In the digester, the sludge is changed into readily disposable products with minimum interference with other plant operations. Organic matter in the sludge furnishes food for anaerobic bacteria. The bacteria breaks the sludge down (digests it) into simple, more stable substances. Under optimum conditions, well-digested sludge is produced in 24 to 26 days. The entire process may take place in one tank or it may be divided into two stages. In two-stage digestion, the relatively violent initial digestion is separated from the slower final period. After the partial digestion in the primary tank, heavier sludge which has settled to the bottom is pumped into the secondary tank where gas evolution and resultant mixing is relatively slow.

b. **Types of Digesters.** Sludge digesters installed as separate treatment units normally are closed structures of sufficient capacity to hold a quantity of sludge equivalent to 30 to 40 days accumulation as calculated from the number of people the unit is expected to serve. Open digesters, such as hoppers and lower compartments of lmhoff tanks, are not as efficient nor as free from odors as the closed digesters. Closed digesters usually are constructed from concrete and steel and have a sloping bottom and either a fixed or a movable top. Digesters of more than one type may be operated at the same treatment plant. Two or more tanks provide flexibility of operation. They can be installed independently as single-stage digesters in parallel or be installed as two-stage digesters in series with one tank a primary and the other a secondary unit.

(1) Fixed cover. This cover is usually made of concrete. It may be flat, with or without space for gas above the liquid level, or it may be dome-shaped with space for gas. It is used for the primary stage of a two-stage digestion process. In lieu of floating covers, and in cold regions, this cover may be used provided a gas collection dome is installed in the top of the cover. At least two access manholes will be provided in the tank roofs. Figure 2-25 shows a fixed-cover and a gas-holder cover digester installed in series.

(2) Floating cover. Tanks with floating covers (see Figure 2-26) are similar to the fixed-cover type, except that the cover floats on the tank's contents. These covers are used for the secondary stage of a two-stage process. Floating covers are on separate digestors. They are used in cold regions where freezing ice and snow are a problem.

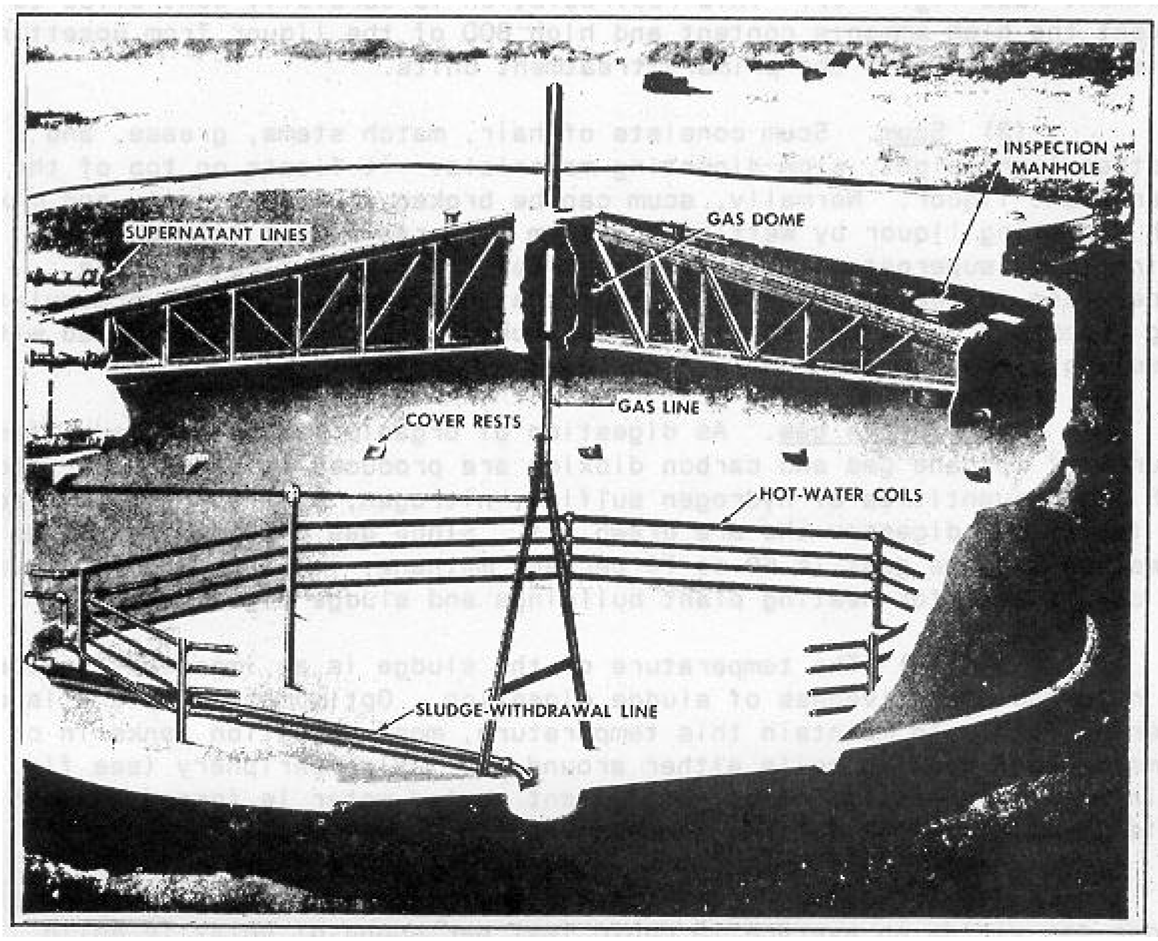


Figure 2-26. Digester with floating cover.

c. **Principles of Operation.** Undigested sludge drawn or pumped from sedimentation units enters the digestion tank near the top and is mixed with digesting sludge already in the tank. As digestion proceeds, four products are formed in the digester -- stable sludge, supernatant liquor, sludge gas, and scum. Within the tank, these substances are found in layers that are rather well defined.

(1) Stable sludge. This is the principal end product of sludge digestion. It is a heavy, black solid residue that is not further reduced by anaerobic bacterial action. It settles on the bottom of the tank and is drawn off for disposal.

(2) Supernatant liquor. The liquid sludge undergoing digestion occupies space in the digester just above the stable sludge. Nonfiltrable residues are found mostly in the lower portion of this liquid or *liquor*. Nitrogenous matter is converted mainly to ammonia, which remains in solution in the liquor. The upper portion of this liquor contains only small quantities of suspended matter. This clarified liquid is called *digester supernatant liquor*. The supernatant liquor commonly is recirculated to primary treatment units and passed again through primary and secondary treatment (see Figure 1-8). This recirculation is carefully controlled to prevent the high ammonia content and high BOD of the liquor from upsetting optimum conditions in the primary treatment units.

(3) Scum. Scum consists of hair, match stems, grease, and a foam of other lightweight, slow-digesting materials. It floats on top of the supernatant liquor. Normally, scum can be broken up periodically and mixed with digesting liquor by wetting the scum with raw sludge influent or recirculated supernatant liquor, mechanical stirring, or raising the temperature inside the digester. Scum that has been allowed to accumulate too long becomes a thick mat that must be broken up by hand. Scum mixed with digesting liquor is eventually digested.

(4) Sludge gas. As digestion of organic matter proceeds, large amounts of methane gas and carbon dioxide are produced. These gases, along with small quantities of hydrogen sulfide, nitrogen, and hydrogen, collect in the top of the digester and are drawn off. Since gas produced by sludge digestion (sludge gas) is 60 to 70 percent methane, it has a high heat value and can be used for heating plant buildings and sludge digesters.

(a) The temperature of the sludge is an important factor in the rate and effectiveness of sludge digestion. Optimum temperature is on the order of 95^0F. To maintain this temperature, most digestion tanks in cold climates have heating coils either around the inside periphery (see Figure 2-27) or in external heating units. Sufficient heated water is forced through the coils to maintain the desired temperature.

(b) Sludge gas for heating purposes will need to be stored. Sludge gas yields on average 15 cubic feet per pound of volatile solid destroyed and has a heat value of between 500 to 700 British thermal units per cubic foot (Btu/cu. ft.). At some plants, however, the gas has been used to produce electric power for operating the plant and for sale to nearby consumers.

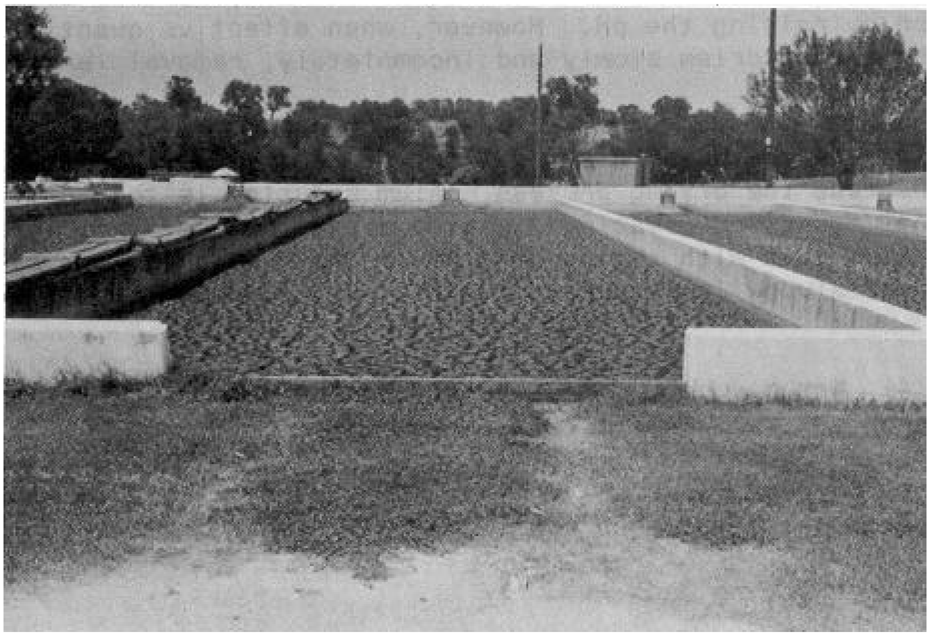


Figure 2-27. Sludge drying bed with concrete walls.

d. **Postchlorination**. The ordinary combined primary and secondary wastewater treatment processes remove or stabilize most of the organic matter present and reduce the bacterial content by 50 percent or more. There is no assurance, however, that the content of pathogenic organisms has been reduced to a satisfactory level unless some disinfection process is applied. Chlorination is frequently applied to a treatment plant effluent just prior to its disposal into a receiving stream. Chlorination at this point is termed *postchlorination*. This chlorination is required when effluents are discharged into bodies of water used for domestic water supply, shellfish culture, training and recreational activities, or irrigation. Where water supplies are taken relatively near the point of outfall, disinfection of effluent is vitally important. Bacterial content of settled or secondary treated effluents is reduced approximately 99.5 percent by chlorination to a residual of 0.3 to 0.5 ppm with a 15-minute contact period. Complete sterilization is not obtained. The chlorine feed rate is proportioned with the flow and the chlorine demand of the wastewater. Adequate mixing during the chlorine contact period is ensured by the installation of adequate baffling or by either mechanical or automatic means.

(1) Manual. When applied manually, the agent may be in either liquid or powder form. Chloride of lime, calcium hypochlorite, and sodium hypochlorite are agents that may be applied by hand and, if so, contact chambers are to be used to effect the required contact time.

(2) Automatic. Commonly used gas-fed machines automatically chlorinate wastewater effluent with chlorine gas. These machines have sensory devices that control the quantity of gas dispensed according to the amount of effluent being discharged.

2-15. SLUDGE DISPOSAL

Well-digested sludge withdrawn from the separate sludge digester or Imhoff tank has a water content of 90 to 96 percent. It is usually granular, has a tar-like odor, and is dark in color. Gray or light brown stripes in the sludge are signs of less-digested material. Total-solids content of well-digested sludge varies from about 4 to 10 percent, the volatile-solids content (dry basis) is below 55 percent, and the pH is over 7.0.

a. **Sludge Drying.**

(1) Digested sludge drying takes place both by evaporation from the surface and by drainage through the sand and gravel generally at the treatment plant. Natural sand areas are sometimes used. Water passing through the bed is returned to the raw-wastewater flow, where possible, or discharged to other points in the plant or to a receiving stream if necessary.

(2) Quick and efficient sludge drying depends first on proper functioning of digesters or Imhoff tanks to produce well-digested sludge. Poorly digested sludge slows the drying process by forming a heavy, tenacious mat over both sand and sludge surface. Also, undecomposed grease clogs the sand. Where digestion is incomplete, the sludge dries poorly and produces objectionable odors. If partly digested sludge or supernatant is drawn to the bed, hydrated-lime or chlorinated-lime suspension may be used to arrest decomposition by raising the pH. However, when effective quantities of lime are used, the sludge dries slowly and incompletely, removal is difficult, and the sand clogs.

(3) If the plant has insufficient sludge-bed capacity, the use of coagulants hastens the drying process. Alum solution is the most effective and economical agent for treating digested sludge before it is drawn to the sand beds. Alum acts with the carbonates in the sludge to form carbon dioxide, which keeps the sludge in suspension while the liquid drains off through the sand.

(4) Wet sludge must not be discharged onto dried or partially dried sludge.

(5) Sludge lines are drained and flushed with a small amount of water or supernatant after each use to prevent sludge from hardening in them.

b. **Sludge Drying Beds**.

(1) Underdrained beds ordinarily are level areas of sand supported by graded gravel layers having open tile drains. Floors are natural earth with dividing and outside concrete, wood or earth walls 12 to 14 inches high. The beds consist of a number of adjacent or independent units (see Figure 2-27). Sludge may take 6 weeks to dry in the summer and 12 weeks in the winter. Glass-covered beds are used if climatic conditions or possible odor nuisance make them necessary.

(2) Sludge beds must be clean before use. After dried sludge is removed and before a new batch is added, the sand surface is loosened by light raking and

leveled with a slight slope away from the point where the wet sludge enters. Sludge chunks, weeds, and other debris are removed. When the sand layer decreases to 4 inches or less because of sand being removed with the dried sludge, clean coarse sand is added. Improper cleaning and preparation of the beds between sludge doses may clog sand surfaces and retard drying. Clogged sand surfaces may be remedied by removing the top 1/4 to 1 inch of sand. At the inlet, sludge must be prevented from falling directly on the sand surface by an adequate splash plate of concrete, brick, masonry, or wood so the surface is not appreciably disturbed.

(3) Filling the bed to excessive depths may clog the bed and lengthen drying time since water must then be lost almost entirely by evaporation. Sand depth varies from 6 to 18 inches, but the optimum drying depth is generally between 8 and 12 inches, depending on solids content. The dried cake should be about 3 to 4 inches thick under normal drying conditions. If the sludge application is comparatively thin, it dries quickly; but the thinner cake requires more labor to remove a unit column than thicker applications. A greater percentage of sand is removed with thin cakes. However, if bed area is limited, digested sludge must be drawn more frequently and applied at a minimum depth so it can dry more quickly.

c. **Sludge Removal and Use.**

(1) Removal from drying beds. Unless large drying areas are available, dried sludge is removed from beds as soon as it can be handled and piled where it is accessible for grinding, hauling, or both. Dried sludge is ready to handle when it can be picked up with a fork without excessive sand adhering to the underside. Moisture content of this sludge usually ranges from 55 to 70 percent.

(2) Use as soil builder. Only well-digested sludge, wet or dried, is used on the post. Sludge is particularly suitable for growing vegetation cultivated for dust and erosion control or for lawns, flower beds and shrubbery. The principal value of dried sludge as a soil builder is the humus content, which averages from 25 to 35 percent. Sludge also has limited power as a fertilizer. On established lawns, pulverized sludge is spread uniformly but not so thick as to blanket the grass and cause blanching. On areas to be seeded, the sludge is spread uniformly and worked into the soil. Sludge must not be applied to crops that are to be eaten raw. The frequent presence of hookworm eggs in sludge may cause infection where climate and soil favor continued hookworm activity. In most areas, health authorities prohibit the use of dried sludge as fertilizer unless it receives further processing for sterilization. The sludge is also checked for the presence of heavy metals. The standards need to be met for the sludge to be used.

(3) Use as fill. Dry sludge may be put on dumps or in low areas. The sanitary landfill and land surface applications are respectively, disposal and utilization methods most suitable for military installations. Trestles or other devices for dumping must be provided since the sludge does not support heavy hauling equipment.

d. **Disposal of Liquid Sludge.**

(1) Fertilizer. In some instances, particularly where drying-bed facilities are deficient, well-digested liquid sludge may be drawn into tank trucks and applied directly as fertilizer to areas being used to grow nonsubsistence crops.

(2) Lagooning. Digested sludge may be discharged from the digesters directly to lagoons instead of to drying beds. The lagoons must be located in isolated areas, preferably where the sludge will flow by gravity. Lagooning of sludge or digester supernatant is generally done only as an expedient when other facilities are inadequate. Lagoon storage can be a continuous operation or can be confined to peak load situations. Land requirements and possible ground water pollution are the major disadvantages.

Section V. FINAL EFFLUENT AND STABILIZATION PONDS

2-16. FINAL EFFLUENT

The final effluent from a wastewater treatment plant is normally discharged into a watercourse or receiving stream. This final effluent must be of such quality that it will not create a nuisance, will not have a harmful effect on the receiving waters, and will be in compliance with all local, state, and Federal standards. Although the effluent from an efficient treatment plant may be relatively free of nonfiltrable residue, BOD, and microorganisms, it is usually quite low in dissolved oxygen content. Therefore, the effluent is provided some type of mechanical treatment to increase the oxygen assets of the receiving stream. One method of adding oxygen to the effluent is by permitting it to flow in open channels, thus absorbing air as it flows. Another method used when there is a sufficient drop in elevation between the plant outflow and the receiving stream is to construct successive steps (cascades) along the waterway. The effluent thus creates a miniature waterfall, thereby absorbing oxygen from the air.

2-17. DECHLORINATION

Dechlorination (partial or complete reduction of residual chlorine) of the effluent may be necessary to comply with applicable Federal, state, and local discharge standards and thus prevent chronic effects on the waste-receiving stream. Dechlorination may be accomplished by sulfur dioxide and its derivatives. Nonchemical means may also be used to accomplish dechlorination (activated carbon, for example).

2-18. STABILIZATION PONDS

a. **General.** A stabilization pond, or oxidation pond, is an artificial shallow pond into which wastewater is discharged for natural purification by biological processes under the influence of air and sunlight. The aerobic bacteria present in the wastewater convert organic matter into carbon dioxide, water, and various nutrients. Algae use these nutrients in their metabolic processes and produce oxygen needed by the aerobic bacteria to continue the cycle. The heavier solids settle to the bottom where they are degraded under anaerobic conditions to produce methane, carbon dioxide, and other gases. Some of the water is lost by percolation and, in dry weather, some is lost by evaporation. Effluents can be used for irrigation or discharged into stream if applicable Federal, state, and local discharge standards are met. The efficiency of a stabilization pond is affected by the detention time, pond depth, organic loading, temperature, light, number of units, and wind. If local pond practices call for organic loadings outside of the standard range, Headquarters, Department of the Army, must approve them beforehand. Stabilization ponds may be aerated by either mechanical or diffused air systems. These devices may be designed to provide sufficient oxygen for biological metabolism and adequate mixing. Mechanical surface aerators are commonly used for this purpose in the southern and temperate climate areas, while diffused air systems have been successful in severe climates where icing may prove troublesome for the mechanical devices.

b. **Uses**. Stabilization ponds may be used for secondary treatment of settled primary effluent, in which case they are called oxidation ponds; or they may be used to treat raw wastewater. Because of the inherent possibility of disagreeable odors arising from stabilization ponds, the ponds should be located a sufficient distance from habitations to prevent creating a nuisance.

c. **Construction**. Stablization ponds are constructed by leveling the required area and surrounding it by a dike of relatively impervious earth. The dikes should be sown with grass or sodded to prevent excessive erosion. Outlet structures, which are located on the windward side, will permit lowering the water level at a rate of not less than 1 foot per week while the pond is receiving its normal flow. Three sets of baffles will be concentrically around the outlet structure(s). The first and third baffles, which extend 3 to 5 feet around the outlet structure, will be located at least 6 inches to 1 foot above the highest water level. The second baffle is set on the bottom of the pond and extends to within 6 inches in the lowest anticipated operating level. The depth may vary from 3 to 5 feet, depending on the area and the quantity of wastewater to be treated. The bottom of the pond will be as level as practicable with variations not exceeding 6 Inches from the designed bottom elevation. Capacity should be sufficient to provide a 30-day detention period. They may be constructed as single cells, cells in parallel, or cells in series. Where the terrain permits, the ponds may be constructed in series at different elevations (see Figure 2-28) connected by shallow weirs. This arrangement permits maximum aeration and oxidation.

d. **Performance**. Stabilization ponds will accommodate up to 50 pounds of BOD per acre of pond area, or roughly 1,000 persons per acre. They should remove from 90 to 95 percent of the BOD and about 90 percent of the coliform bacteria. Ponds with detention times of about 50 days will remove 99 percent of the coliform bacteria.

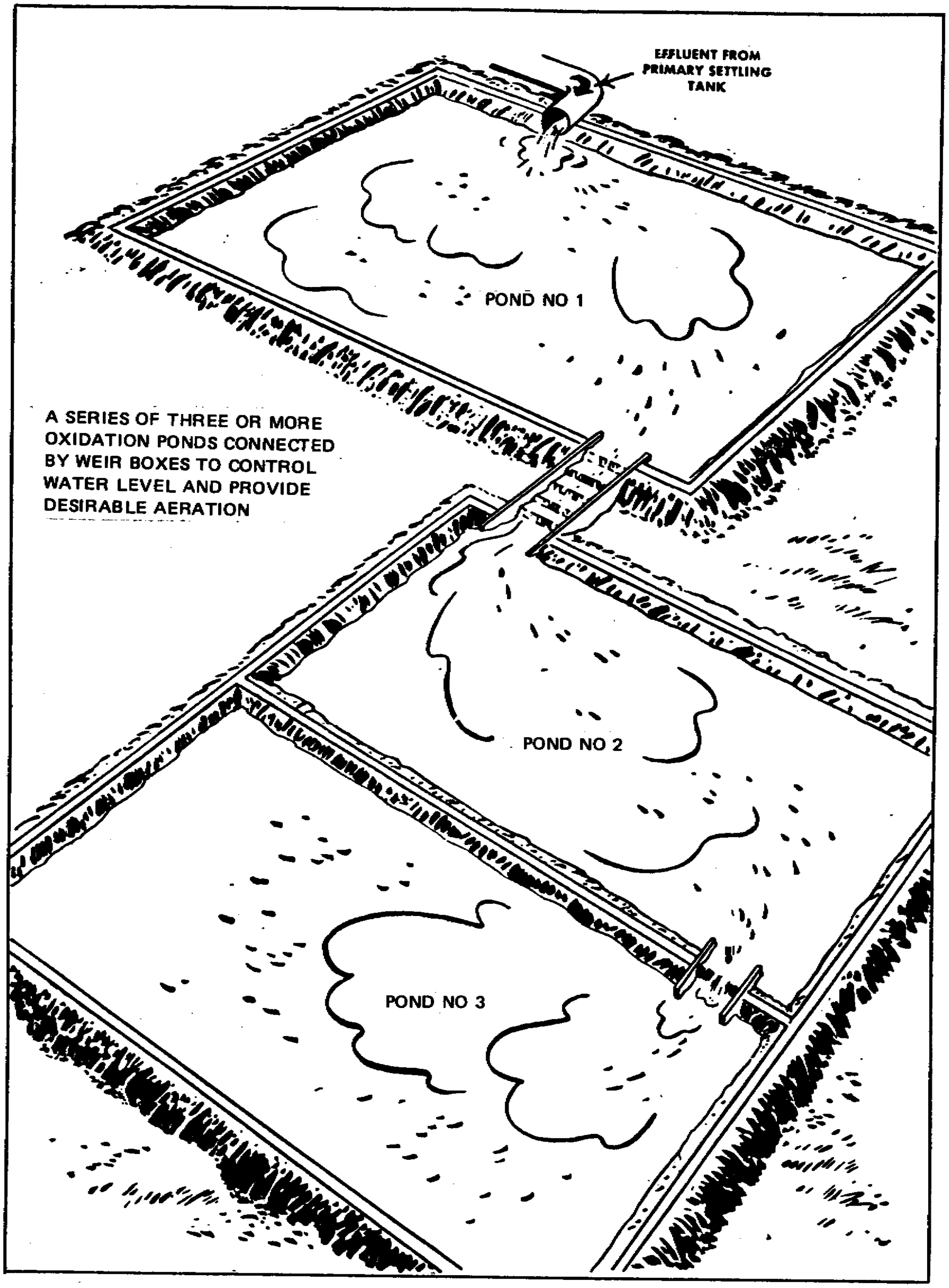


Figure 2-28. Oxidation ponds.

e. **Maintenance**. Stabilization ponds are simple in operation, but they do require a minimum of maintenance. Weeds and mosquitoes must be controlled. One way to control mosquitoes is to stock the pond with surface-feeding fish, such as gambusia. Scum must sometimes be removed. Though much less frequently, sludge must sometimes be removed also. Therefore, provisions should be made in construction for draining ponds.

Section VI. PACKAGE WASTEWATER TREATMENT PLANTS

2-19. GENERAL

Small installations have several options available for wastewater treatment. They may utilize the wastewater systems of neighboring communities, when possible. If permitted, they may install soil absorption systems. If sufficient land area is available, they may construct stabilization ponds. If none of these options are available, the package wastewater treatment plant should meet their needs. The term "package" as applied to wastewater treatment plants usually means a compact, relatively simple to operate unit designed to give complete treatment to the wastewater from a small community. Figure 2-29 illustrates the package unit for such a treatment plant. Package plants are generally installed where a high degree of biochemical oxygen demand removal is required but other factors prohibit the use of conventional types of secondary treatment. Units of this type are often used also for treatment of industrial wastes.

2-20. PRINCIPLES OF OPERATION

Most of the plants currently being used employ a modification of the activated-sludge process. The conventional activated-sludge plant aerates settled wastewater and return activated sludge at a mixed-liquor suspended solids concentration of about 2000 milligrams per liter for about 6 hours. The activated sludge is then settled in a secondary settling tank. Return sludge amounting to about 25 percent of the influent flow is recycled ahead of the aeration tank. The remainder of the activated sludge is wasted. The modifications to the activated sludge process that are used for package plants are the extended aeration process and the contact stabilization process.

a. **Extended Aeration**. Most extended aeration plants by-pass primary settling and aerate the mixed-liquor suspended-solids for about 24 hours at a concentration of about 5000 milligrams per liter. Return sludge for these plants is usually about 100 to 150 percent of the influent flow. Because of the long aeration times and low food to microorganism ratio (low organic loadings of less than 20 pounds BOD per 1,000 cubic feet of aeration tank volume), synthesis rates are low and a low buildup of residue results. Because of the low residue buildup, a digestion unit is not needed. This aeration is considered an option in larger plants.

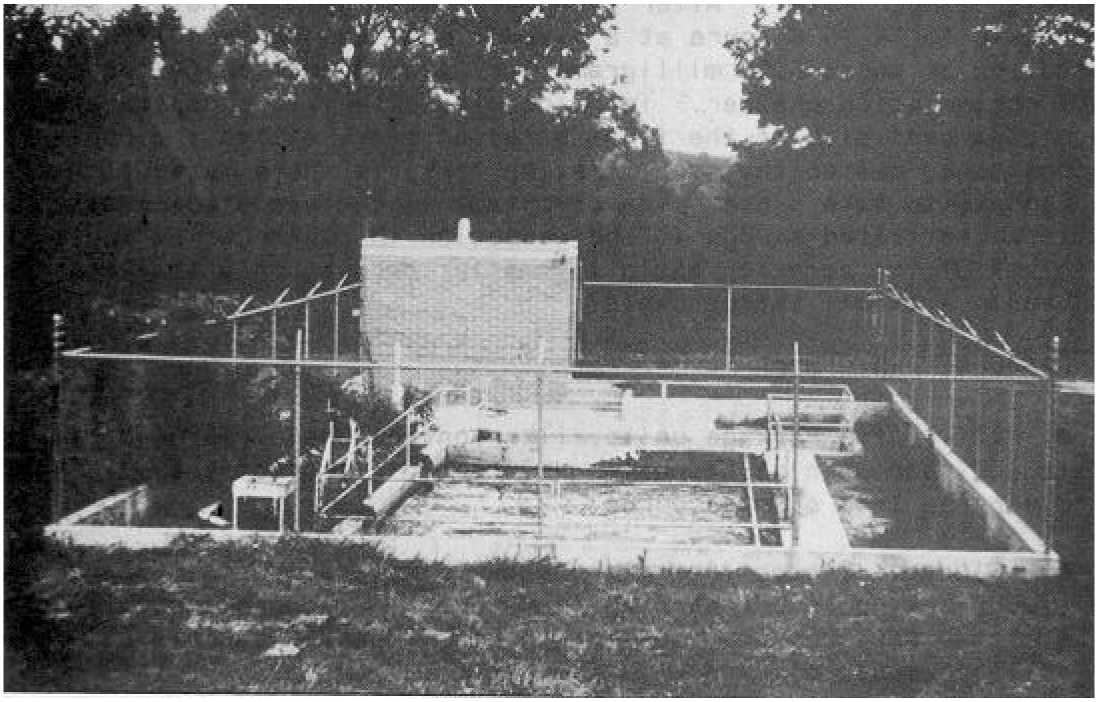


Figure 2-29. Package wastewater treatment unit.

b. **Contact Stabilization**. The other modification that is used in package plants is called contact stabilization. An overload conventional activated sludge plant can be upgraded by converting the existing aeration tank to two separate aeration tanks or basins. For this process, in the first basin, primary effluent and activated sludge are mixed and aerated for about an hour and a half at a mixed-liquor suspended-solids concentration of about 2500 milligrams per liter. After secondary settling, the return sludge is aerated again for 4 to 8 hours at a mixed-liquor suspended-solids concentration of about 8000 milligrams per liter before being recycled ahead of the first aeration chamber. In principle, dissolved organics are adsorbed on the sludge particles in the first aeration tank, called the contact tank. The second tank, called the stabilization tank, is where metabolism of the wastes is said to take place. The advantage of contact stabilization over conventional activated sludge is the reduction in construction cost. The total volume of the aeration basin is smaller because only the return sludge is aerated in a stabilization basin.

2-21. EFFLUENT AND SLUDGE

a. **Effluent**. Package units, like conventional treatment plants, are routinely equipped with chlorination devices to disinfect the effluent prior to its discharge into a watercourse.

b. **Sludge**. Sludge from package units may be disposed of by discharge into a sludge-drying bed, a holding tank, or by pumping directly into a tank truck as with a septic tank. The method of sludge disposal is determined largely by the amount of land area available.

2-22. MAINTENANCE AND EFFICIENCY

a. **Maintenance**. Although package plants are designed for simple operation, they are by no means maintenance free. A qualified operator should be assigned to perform necessary maintenance and tests. Normal maintenance includes checking equipment for proper operation, lubricating, cleaning, housekeeping and groundkeeping, maintaining supplies, and washing off excess residue (sludge). Simple tests to determine the efficiency of the plant may include analysis for residues, residual chlorine, and pH.

b. **Efficiency**. When properly operated, package plants can be as efficient as large treatment plants. Removal of up to 90 or 95 percent of nonfiltrable residue can be expected.

Section VII. OPERATIONAL TESTS AND SAMPLING

2-23. OPERATIONAL TESTS

The purpose for the principal tests conducted in a conventional wastewater treatment plant and the significance of each is listed below. However, the list is not all-inclusive. The discharge permit from the governing Federal, state, and local regulatory agency will specify the tests that are to be conducted. Details of the conduct of each test are a technical subject beyond the scope of this subcourse.

a. **Purpose of Tests**. Wastewater is sampled and analyses are made to:

(1) Determine strength and composition of wastewater.

(2) Determine the overall efficiency of the treatment process.

(3) Control the various wastewater treatment processes.

(4) Predict effects at the point of final disposal.

(5) Determine actual results of treated wastewater discharge.

(6) Verify compliance with appropriate discharge permit.

(7) Compile records and data for future use.

b. **Residues**. Determination of the residue content of wastewater at various points in the treatment process indicates the efficiency of removal during various individual treatment processes. The residues in wastewater are in suspension and in solution. Grouped together, nonfiltrable residues and filtrable residues comprise the total residues. The nonfiltrable residues consist of settleable residues and nonsettleable residues. Most of the nonsettleable residues are very finely divided. The residues in wastewater are also classified as fixed residues and volatile residues. The fixed residues are the materials remaining after the volatile residues have been ignited or driven off by heating.

(1) Total residues. The total residues (total solids) are determined by evaporating a known volume of wastewater over a steam bath, drying the residue, and determining the weight of the residue. This test is used to determine the efficiency of sludge digestion.

(2) Nonfiltrable residues. The nonfiltrable residues (suspended solids) are found by filtering a known volume of wastewater, drying the filtered material, and determining its weight. This test is used to determine the efficiency of both primary and secondary processes (except for sludge digestion).

(3) Settleable residues. Settleable residues (settleable solids) are determined in two ways--by volume and by weight. The simple test by volume is made by allowing a one-liter sample of wastewater to settle for about one hour in a quiescent condition in a specially designed (lmhoff) cone. The quantity of material that collects in the bottom of the cone is reported in milliliters per liter. The more accurate method of determining settleable solids is to allow the sample to stand quiescently in the lmhoff cone, siphon off the supernatant, evaporate the settled solids to dryness, and weigh the residue. The number of milligrams of the material weighed is the parts per million of settleable solids in the sample. This test is also used to determine the efficiency of primary and secondary processes as in (2) above.

(4) Fixed and volatile residues. If the dried and weighed filtered residues obtained from the total residues determination are ignited (tat is, heated sufficiently to burn off the volatile matter), the weight of the remaining substances is the weight of the fixed residues or approximately the weight of the mineral matter. The difference between this value and the weight of the dried (unignited) residues is the weight of the volatile residues, or approximately the weight of the organic matter. This test is used with (1) above to determine the efficiency of sludge digestion.

c. **Biochemical Oxygen Demand (BOD).** The BOD of a liquid is defined as the quantity of oxygen required for the biochemical oxidation of the decomposable (organic) matter at a specified temperature, within a specified time (usually 5 days at 20°C), and under specified conditions. The BOD indicates the amount of decomposable organic matter in the wastewater, is an index of the concentration of the wastewater, and aids the engineer In evaluating both plant efficiency and effluent effect on receiving streams.

(1) Determination of the BOD. The recommended method of determining the BOD is to dilute a known volume of wastewater with a known volume of specially prepared dilution water that is saturated with dissolved oxygen. The dissolved oxygen content of the mixture is determined at the beginning and at the end of the incubation period on separate bottles of the wastewater dilution water mixture. The difference or depletion in oxygen is corrected for the loss of oxygen in a similarly incubated sample of

dilution water. This figure is multiplied by the dilution factor and the final result is the BOD of the wastewater.

(2) Evaluation of BOD. The BOD has proven to be the best single test for measuring the progressive and overall efficiency of wastewater treatment processes and for indicating the probable effect of the plant effluent upon the receiving body of water. The major disadvantages of the test are the length of time necessary for obtaining values plus the fact that the results cannot immediately be translated into control procedures. The test is relatively complicated, but in the hands of the skilled operator meaningful results are obtained.

d. **Dissolved Oxygen**. The dissolved oxygen determination is made to ascertain the quantity of atmospheric oxygen, which is dissolved in the given sample of water or wastewater. It is also the major analytical step in the BOD determination. In collecting a sample for this test, extreme care must be exercised in order to avoid the entertainment or absorption of any oxygen from the air. The temperature of the wastewater sample should also be recorded to the nearest degree Celsius. The test should be carried out immediately after collection of the sample.

e. **pH.** The pH test measures the acidity or alkalinity of wastewater and is useful in indicating whether it is fresh or septic during the collection system or during any other wastewater treatment process. The test is performed by using certain dyes or indicators which exhibit color changes at different levels of hydrogen ion concentration. If the sample to be tested is colored, electrometric instruments are used to make the determination.

f. **Chlorine Demand**. The chlorine demand test of a wastewater is made to determine the chlorine required to be added to the wastewater to produce a trace chlorine residual. The chlorine demand is determined by adding a sufficient quantity of a standard chlorine solution to a sample of wastewater until a yellow color is developed with the addition of orthotolidine solution. This amount is called the immediate chlorine demand.

g. **Residual Chlorine**. Residual chlorine can be determined by the old orthotol iodine test or the newer N, N-diethyl-p-phenylenediamine (DPD) test. The orthotolidine test can be used until new equipment is acquired. When new equipment is acquired, the DPD test equipment should be used. Both tests consist of adding a small quantity of the appropriate reagent to the wastewater and comparing the resulting color with the correct color standard. Each test is used to measure the chlorine residual in the plant effluent; however, the DPD method is preferred.

2-24. SAMPLING

a. **General.** Wastewater samples are collected by plant operating personnel for regular, periodic laboratory tests to assist in proper plant operation and control. Army Medical Department personnel collect samples for the purpose of conducting investigations and surveys.

b. **Representative Sampling**. Wastewater samples must be as nearly representative of the entire body of wastewater being tested as possible. Errors in sampling too often nullify the accuracy of laboratory tests. Intermittent pumping of wastewater in the conducting channel causes the character of layers or stratas of residue in the conducting channels to change, making it difficult to get representative samples. Analyses should be conducted as soon after collection of the samples as possible; otherwise, the biochemical processes that take place within the sample itself may render the test results meaningless.

(1) Grab samples. A grab sample is defined as a sample taken one time at any one point. The results of a grab sample indicate only the momentary condition existing at the particular time of collection at the particular rate of flow past a particular point and are useful for immediate control purposes. Some tests which require grab sampling are dissolved oxygen, chlorine demand, residual chlorine, settleable residues, pH, mixed liquor and return sludge concentration (for activated sludge), and digester content tests. Grab samples are also used in making stream surveys to monitor the effect of the plant effluent on the receiving stream.

(2) Composite samples. For determining total loading on a plant, the overall treatment efficiency of the plant, and the pollution load on the receiving stream, it is necessary to know the average daily composition of the wastewater as it passes through the plant. For this purpose, a composite sample is obtained. To make a composite sample, individual samples are gathered at regular intervals over a selected time period (usually 16 to 24 hours), proportioned according to hourly flow past the sample point, and composited for analysis. Composite samples are taken for the following determinations: nonfiltrable residue; biochemical oxygen demand (BOD); and total and volatile residue of sludge, grease, and nitrogen.

(3) Sampling points. Samples from channels are taken at two-thirds the depth of the flow at a point free from back eddies. Samples of digester sludge are collected at 3- to 5-foot intervals, starting at the top and working down to avoid agitating the sludge from which the succeeding samples are taken. Figure 2-30 shows the samplers used for wastewater effluent and sludge. Sampling for dissolved oxygen requires special procedure and apparatus (see Figure 2-31) to prevent an increase in oxygen content through contact with air.

c. **Schedule of Analyses.** Table 2-1 is a suggested schedule of sampling and analyses. Unless otherwise indicated by footnotes in the table, grab samples and analyses are made daily. Analyses requiring composite samples are made every 6 days at plants serving populations between 1,500 and 6,000; every 3 days for populations between 6,000 and 20,000; and daily when the population served exceeds 20,000. Samples from digesters and Imhoff tank sludge compartments are taken monthly and samples from streams receiving the plant effluent are taken weekly. Where the population is less than 6,000, the minimum analyses to be made are daily grab-sample tests for settleable residue, pH, and chlorine residual. It should be noted that revisions may be necessary to comply with the appropriate Federal, state, or local regulatory agency having jurisdiction.

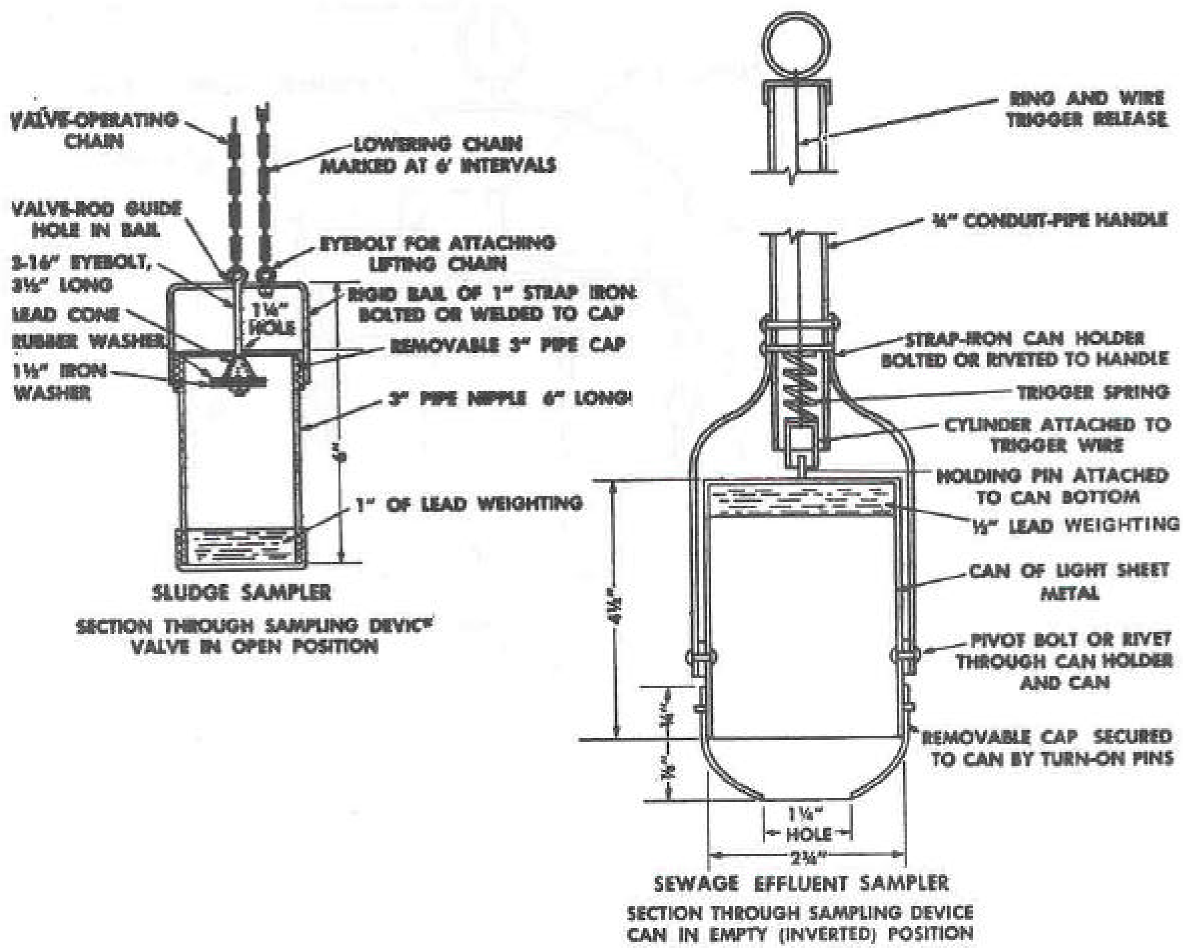


Figure 2-30. Sampler for sludge and wastewater effluent.

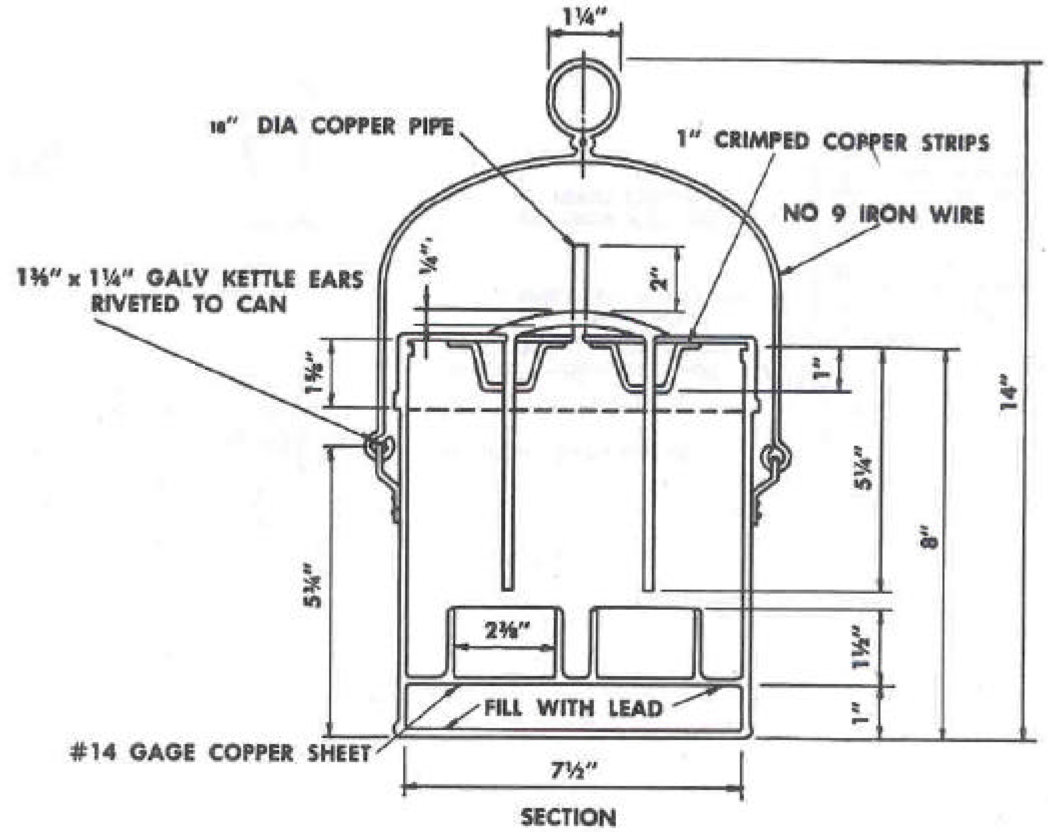


Figure 2-31. Apparatus for collecting dissolved-oxygen samples

Sampling point	Temperature	pH	Settleable solids	Suspended solids	Dissolved oxygen	BOD	Percent relative stability	Percent total solids	Percent volatile solids	Residue chlorine
Primary treatment:										
Plant influent----	G	G	CG[1]	C		C				
Plant effluent (primary)--------		G	CG[1]	C		C				G[3]
Trickling filters:										
Filter effluent----				C		C				
Activated sludge:										
Mixed liquor-----			G[1]	G[1]	G[1]					
Return sludge---			G[1]	G[1]						
Plant effluent (final)	G		CG[1]	C	G	C	G[2]			G[3]
Sludges sampling:										
Raw sludge (daily)		G						C	C	
Digested sludge (as drawn)------		G						C	C	
Digester sampling (monthly)------	G	G						G	G	
Supernant (weekly)--------		G						C		
Steam samples–Weekly-------	G				G	G				

C–Composite samples.
G–Grab samples.
[1]Once per shift.
[2]Before chlorination.
[3]Hourly.

Table 2-2. Sampling mg and analysis schedule.

Continue with Exercises

EXERCISES, LESSON 2

INSTRUCTIONS: Answer the following exercises by marking the lettered response that best answers the exercise, by completing the incomplete statement, by providing more than 1 response (where applicable), or by writing the answer in the space provided at the end of he exercise.

After you have completed all these exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. Primary wastewater treatment processes include which of the following?

   a. Aeration.

   b. Filtration.

   c. Removal of sand and grit.

   d. Removal of nonfiltrable residue by sedimentation.

   e. Reduction of putrescible solids to more stable substances.

2. Screenings containing putrescible material may be disposed of in which of the following ways?

   a. By burial.

   b. As hog feed.

   c. By incineration.

   d. As fertilizer for crops.

   e. By grinding and digesting with sludge.

3. Grit accumulations from grit chambers may be used for landfill if they do not contain _______________ material.

4. The purpose of a Parshall flume is to:

   a. Measure the rate of wastewater flow.

   b. Ensure addition of chlorine at a constant rate.

   c. Reduce the velocity of flow into the grit chamber.

   d. Maintain a constant rate of flow into the primary settling tank(s).

5. Metering of wastewater flow is necessary to:

   a. Prepare grab samples properly.

   b. Prepare composite samples properly.

   c. Add chlorine to the effluent at the proper level.

   d. Determine the quantity of wastewater handled by the plant.

   e. Know the velocity of the flow at all points in the plant at all times.

6. Most of the settling in primary settling tanks occurs during the first:

   a. 30 minutes.

   b. Hour.

   c. 2 hours.

   d. 4 hours.

7. The normal detention time for average daily flow in primary settling tanks is ____________________________ .

8. Sludge must be removed from plain sedimentatlon tanks frequently to prevent the development of __________________________ conditions.

9. Septic conditions are avoided in the lower part of the lmhoff tank by:

   a Frequently removing scum.

   b. Frequently removing of sludge.

   c. Maintaining a constant rate of flow through the tank.

   d. Preventing bubbles from rising through the upper (settling) compartment because of the conFigureuration of the tank.

   e. None of the above is correct.

10. Sludge of proper consistency for removal may be recognized by:

    a. Odor.

    b. Taste.

    c. Appearance.

    d. Test results.

    e. All of the above.

11. Name one accomplishment when aerobic processes are employed during secondary wastewater treatment?

    a. Solids are removed by chemical action.

    b. Solids are removed by biological action.

    c. Organic matter is settled out by plain sedimentation.

    d. Solids are converted by biomedical action into stable substances, which may then be removed by sedimentation.

12. Anaerobic wastewater treatment processes are characterized by the production of:

    a. Helium.

    b. Oxygen.

    c. Ammonia.

    d. Methane.

    e. Hydrogen sulfide.

13. Why is the "trickling filter" actually a misnomer?

    a. Because the action is not physical as in a conventional filter, but biochemical.

    b. Because the effluent does not trickle, but is distributed by a rotating arm or a fixed spray.

14. How do high capacity trickling filters differ from low capacity filters?

    a. They are much larger in diameter.

    b. The wastewater is applied at a higher rate of flow.

    c. Schmutzdecke is retained on the filter medium for longer periods of time.

    d. Wastewater which has already passed through the filter is recirculated.

15. What is the significance of the <u>Psychoda</u> filter fly?

    a. It is related to the <u>Phlebotomus</u> fly.

    b. It is an annoyance to plant personnel.

    c. The larvae interfere with biological action in the filter.

    d. Heavy infestations of larvae may clog trickling filter medium.

16. The filtration unit is used:

    a. As a means of disposal without surface effluent.

    b. As secondary treatment, following primary settling.

    c. To clarify digester supernatant for recycling to trickling filters.

    d. In lieu of primary settling tanks, to filter out nonfiltrable residue.

17. Activated sludge is:

    a. An inert, biologically stable substance recovered from primary settling tanks.

    b. A septic, highly volatile substance in which anaerobic decomposition is taking place.

    c. A biologically active material containing numerous organisms and organic material in various stages of decomposition.

    d. Sludge from primary settling tanks which has been activated by the addition of anaerobic bacteria to aid in the digestion process.

18. How does activated sludge differ from sludge from primary settling tanks?

    a. Primary sludge is only 95 percent water, where as activated sludge is 99.9 percent water.

    b. Primary sludge is relatively odorless, while activated sludge has a pungent, disagreeable odor.

    c. Primary sludge is inactive, stable material, while activated sludge is active, volatile material.

    d. Primary sludge consists mainly of settleable solids, whereas activated sludge contains large quantities of dissolved fine organic matter that have been absorbed by the sludge.

19. Activated sludge Is formed by.

    a. Diffused air aerators.

    b. Primary settling.

    c. Mechanical aerators.

    d. Adding activated bacteria to digested sludge.

20. The stable products formed by biochemical wastewater treatment processes are removed by ________________ ___________________, an essential part of secondary treatment.

21. Approximately ____________ percent of the sludge from primary sedimentation units is putrescible organic solids.

22. Under optimum conditions, well-digested sludge is produced in approximated ___________ days.

23. What products are formed In a sludge digester?

    a. Scum.

    b. Oxygen.

    c. Sludge gas.

    d. Schmutzdecke.

    e. Zoogeal film.

    f. Stable sludge.

    g. Activated sludge.

    h. Supernatant liquor.

24. What is the normal method for disposing of supernatant liquor?

____

25. The most important factor in sludge disposal is:

a. Ensuring that the sludge is well digested.

b. Adequate area for drying beds.

c. A favorable climate (humidity).

d. Sufficient underdrain for proper dewatering.

26. The expected result in properly control led postchlorination of plant effluent is the:

a. Removal of all BOD.

b. Complete sterilization.

c. Reduction of the bacterial content by approximately 99.5 percent.

d. Imparting of a residual which will preserve the potability of the receiving stream.

27. ______________ is sometimes added at the plant inlet to prevent septic conditions and to prevent odors.

28. An advantage of the stabilization ponds is:

a. Simplicity.

b. Freedom from maintenance.

c. Freedom from insect pests.

d. Freedom from objectionable odors.

29. Package wastewater treatment plants are:

    a. Compact.

    b. Portable.

    c. Maintenance free.

    d. More efficient than conventional treatment plants.

    e. Well-adapted to the needs of a small installation (or community).

30. Tests for the residue content of wastewater at various points in the treatment process indicate:

    a. The efficiency of residue removal.

    b. The chemical composition of the residue.

    c. The effect of the residue on the receiving waters.

    d. All of the above.

31. The BOD test normally requires __________ days.

32. The principal advantage of the BOD test is that it:

    a. Is the best single test for measuring overall efficiency.

    b. Requires the U.S. Army medical laboratory to run the test.

    c. Has a low degree of correlation between treatment processes and effluent quality.

    d. Provides results, which are immediately available for implementing control procedures.

33. The best type of sample for determining the momentary condition existing at a given time and a given point is the _____________ sample.

34. Which tests require special procedures and apparatus for collecting samples?

   a. BOD.

   b. Dissolved oxygen.

   c. Residual chlorine.

   d. Nonfiltrable residue.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 2

1. c
   d (paras 2-1, 2-5(a))

2. a
   c
   e (para 2-2b(3))

3. Organic (or putrescible). (para 2-3)

4. a (para 2-4b)

5. b
   c
   d (paras 2-4, 2-14b, 2-24b)

6. b (para 2-5b)

7. 2.5 hours. (para 2-5b)

8. Septic. (para 2-5a)

9. e Septic conditions in the lower compartment (sludge digestion) are a design feature of the Imhoff tank. (paras 1-10a(3), 2-5c(3), 2-6a)

10. c
    d. By experience, an operator learns to correlate appearance and test results. (para 2-6b)

11. d (para 2-7a)

12. c
    d
    e (para 2-7b)

13. a (para 2-8b(2))

14. b
    d (para 2-8b(3) (b) 1)

15. b
    d Fly larvae assist in the biological action, provided the infestation does not become excessive. (para 2-8b(4)(d)1)

16. a
    b (para 2-8c(2))

17. c (para 2-8d(2))

18. d (paras 2-5a; 2-8d(1),(2))

19. a
    c (para 2-8d (4)(a),(c))

20. Secondary sedimentation. Note: An exception is the intermittent sand filter, which does not require a settling tank. (para 2-9a)

21. 5 (para 2-14a)

22. 24-26 (para 2-14a)

23. a
    c
    f
    h (para 2-14c)

24. By recirculation through the primary units. (para 2-14c(2))

25. a (para 2-15a(2))

26. c (para 2-14d)

27. Chlorine (para 2-3c)

28. a (para 2-18)

29. a
    e They are compact, but not portable (see Figure 2-29). They require less maintenance than conventional plants, but they do require maintenance. They can be as efficient as conventional, but they are not necessarily more efficient. (paras 2-19 thru 2-22)

30. a (para 2-23b)

31. 5 (para 2-23c)

32. a (para 2-23c(2))

33. Grab. (para 2-24b(1))

34. a
b (paras 2-23c, d; 2-24b(3))

End of Lesson 2

LESSON ASSIGNMENT

LESSON 3 Field Waste Disposal Methods.

TEXT ASSIGNMENT Paragraphs 3-1 through 3-8.

LESSON OBJECTIVES After completing this lesson, you should be able to:

3-1. Select the statement which best describes the essential features in the construction, operation, and maintenance of human waste disposal in the field.

3-2. Select the statement that correctly describes the type and amount of human waste disposals for specific field conditions.

3-3. Identify the statement which best describes the correct disposal of other liquid wastes.

SUGGESTION After studying the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 3

FIELD WASTE DISPOSAL METHODS

Section I. HUMAN WASTE DISPOSAL

3-1. GENERAL

a. The basic requirement for waste disposal under field conditions is the same as for a permanent installation; that is, wastes must be disposed of in such a way as to preclude contamination of surface or subsurface waters, attraction of rodents and insects, creation of a nuisance, or violation of Federal, state, or local pollution abatement laws or regulations. Field and installation requirements differ. The commander, rather than the engineer, is responsible for the construction and maintenance of waste disposal facilities under field conditions. Whereas waste disposal facilities on an installation are permanent in nature, those used in the field are generally improvised and temporary.

NOTE: For good preventive medicine practice, contact the preventive medicine service/section or team at your installation or local field unit.

b. During time of war, a commander must exercise a high degree of resourcefulness, as well as look out for the health and safety of the soldiers. Wars are fought under conditions ranging from primitive, harsh circumstances to situations which would be considered comfortable in time of peace. When adequate buildings and facilities are available in a hostile environment, the commander must determine whether the added health benefit of utilizing such facilities offsets the lack of tactical concealment and the hazard from partisans. When adequate facilities are not available or when the commander chooses not to use available facilities, improvised facilities must be constructed to ensure the maintenance of proper sanitary standards within the command. As with the first camps set-up in Saudi Arabia for the Persian Gulf War of 1991, commanders found out quickly that filthborne diseases caused by unsanitary human waste disposal conditions resulted in soldiers coming down with dysentery and diarrhea. Because diarrhea, vomiting, and abdominal pain can be abrupt and last up to several days, soldiers were rendered combat ineffective. Sanitary shortfalls were noted by AMEDD personnel when they inspected the waste facilities and the methods of operation. Recommended changes were made to the commanders and immediate corrections were implemented. The devices or types and methods of human and liquid waste disposal discussed in this lesson have been devised to meet the criteria of simple construction and adequate sanitation.

c. For many years, it has been standard Army practice during field training to simulate combat conditions as nearly as possible. However, because of the large number of troop units which have repeatedly used the same training areas both in the

United States and overseas, pollution and contamination of the soil have become serious problems. Most major commands now require that units in the field use some type of human and liquid waste collection method (chemical toilets, bucket or pail latrines, etc.) that permit disposal into a wastewater collection system periodically or at the end of the field exercise. Accordingly, commanders should acquaint themselves with the pollution abatement directives of the appropriate command prior to constructing field waste disposal devices in normal training areas.

3-2. LATRINE FACILITIES

The following general rules apply to the construction of all types of latrines except the "cat hole." As a guideline, latrines should be constructed to accommodate 4 percent of the male and 6 percent of the female population within a command at one time. Urine facilities for males (para 3-5) should be collocated with the latrines to prevent soiling of toilet seats. For temporary camping of 1 to 3 days, the straddle trench latrine should be constructed unless a more permanent facility is provided to the unit. Thus, based on 2 feet (ft) of trench per person, a unit composed of 100 men and 100 women (for example) would have at least 8 feet or trench, or two 4-foot straddle trench latrines for the men (100 men x .04 = 4 x 2 ft per male = 8 ft of trench) and at least 12 feet of trench or three 4-foot straddle trench latrines for the women (100 women x .06 = 6 x 2 ft per female = 12 ft of trench). For a slightly longer time, deep pit latrines and urine soakage pits would be used.

a. **Location.** To make sure that food and water wiII be protected from contamination, latrines should be built at least 100 yards from the unit dining facility and 100 ft. (about 30 meters) from the nearest water source or supplies. Also, the latrine should be dug above the natural water level in the ground (water table) and on level ground, but not in a place where it may drain into any other water source. Usually, latrines are built at least 30 yards from the end of the unit area (*always downhill from the campsite)*, but within a reasonable distance for easy access. At night, they should be lighted if the military situation permits. If lights cannot be used, a piece of cord or tape may be fastened to trees or stakes to serve as a guide to the latrine.

b. **Screening.** A canvas or brush screen should be placed around each latrine, or the latrine may be enclosed within a tent.

(1) In cold climates, this shelter should be heated if possible.

(2) The screen or the tent should have a drainage ditch dug around its edges to prevent water from flowing over the ground into the latrine.

(3) For fly control, shelters should be sprayed twice weekly with an approved insecticide. If a fly problem does exist, spray the pit contents with insecticide. However, the pit contents should not be sprayed routinely because flies can develop a resistance to the pesticide when used repeatedly and negate its intended purpose.

c. **Handwashing Devices.** A simple handwashing device should be installed outside each latrine enclosure. The device should be easy to operate and constantly supplied with water. The importance of handwashing devices must be given aggressive emphasis since hands contaminated with fecal material are a common means of disease transmission. A soakage pit should be provided for these devices. An ample supply of soap is to be available at all times.

d. **Policing.** Latrines should be policed every day. Certain unit personnel should be assigned the responsibility of ensuring that the latrines are being properly maintained.

e. **Night Alternative.** If the latrine is located some distance from the sleeping area, a large can or pail may be placed at a convenient location in the area for use as a urinal at night. The can used for this purpose must be emptied into the soakage pit every morning and washed with soap and water before being reused.

f. **Closing.** When a latrine pit has been filled to within one foot of the surface or when it is to be abandoned, remove the latrine box and close the pit.

(1) Fill the pit to the ground surface with successive, 3-inch layers of earth. Pack each layer down so that a compacted layer of 1 foot remains. The purpose of this method of closing is to prevent any fly pupa that may hatch in the closed latrine from getting out.

(2) Place a rectangular sign on top of the mound. The sign must indicate "closed latrine" and the date it was closed.

3-3. LATRINES USED IN NORMAL WATER TABLE AREAS

a. **Cat Hole.** The simplest of all field latrines is the "cat hole" (see Figure 3-1). This method is used by the individual on the march, on patrol, or in similar situations where no latrine facilities are available. The individual simply digs a hole about a foot wide and 6 to 12 inches deep. After use, the hole is covered and packed immediately.

b. **Straddle Trench Latrines.** The most common type of latrine for temporary bivouacs of 1 to 3 days' duration is the straddle trench latrine (see Figure 3-2). A straddle trench latrine is usually dug 1 foot wide, 2 1/2 feet deep, and 4 feet long. This will accommodate two people at the same time. Thus a unit composed of 100 men and 100 women would have two-4 foot straddle trench latrines for the men (100 men x .04X =4 x 2 ft per male = 8 ft of trenches) and three-4 foot straddle trench latrines for the women (100 women x .06X = 6 x 2 ft per female = 12 ft of trenches). The trenches should be at least two feet apart. There are no seats in this type of latrine, but boards may be placed along both sides of the trench to provide better footing. Toilet paper should be placed on suitable holders and protected from bad weather by a tin can or other covering. The earth removed in digging is piled at the end of the trenches. A shovel or paddle is provided so that each individual can properly cover his excreta and toilet paper. When the unit leaves the area or when the straddle trenches are filled to within one foot of the surface, the trenches should be closed in the manner described in paragraph 3-2f.

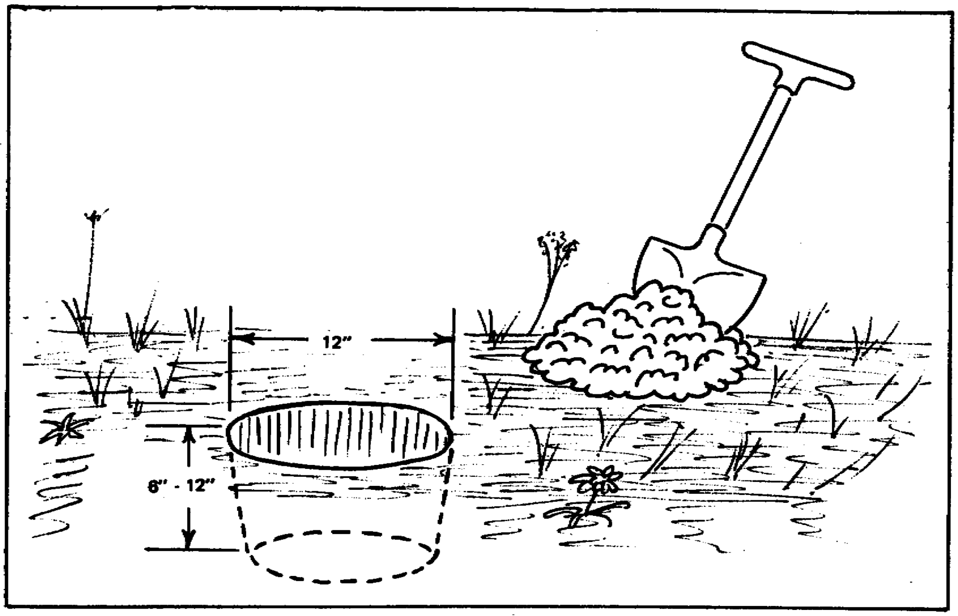


Figure 3-1. Cat hole.

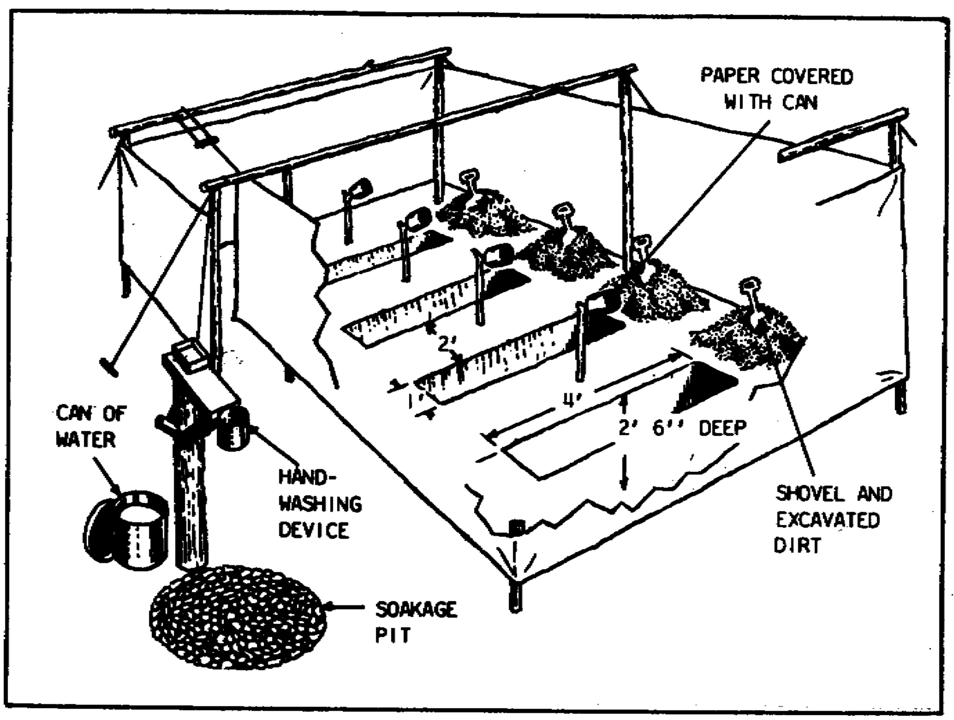


Figure 3-2. Straddle trench latrine with hand-washing device.

c. **Deep Pit Latrines.** The deep pit latrine is used with a latrine box placed over it. The standard type box provides four seats and is 8 feet long and 2 1/2 feet wide at the base. A unit of 100 men requires 8 feet of latrine space, or one 4-seat latrine box (see Figure 3-3). The holes should be covered with flyproof, self-closing lids. All cracks should be flyproofed with strips of wood or tin nailed over them. A metal deflector should be placed inside the front of the box to prevent urine from soaking into the wood. The deflector may be made with flattened cans.

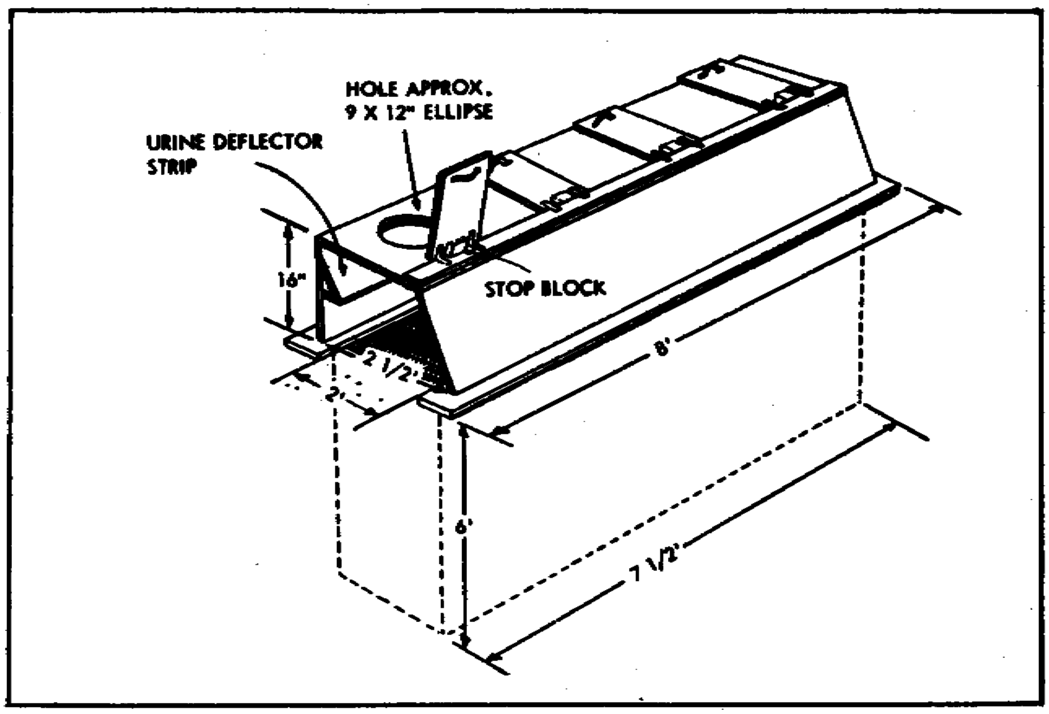


Figure 3-3. Deep pit latrine.

(1) Construction. The pit is dug 2 feet wide and 7 1/2 feet long. This will give the latrine box 3 inches of support on all sides. The depth of the pit will depend on the estimated length of time the latrine is to be used. As a rough guide, a depth of one foot is allowed for each week of estimated use, plus one foot of depth for the dirt cover, when closed. Generally, it is not desirable to dig the pit more than 6 feet deep because the walls might cave in. Rock or high ground water levels often limit the depth of the pit. In some types of soil, a support of planking or other material for the sides may be necessary to prevent wall cave-ins. Earth should be packed tightly around the bottom edges of the box so as to seal any openings through which flies might gain entrance.

(2) Sanitation. In order to prevent flybreeding (deposit and hatching of eggs) in the pit and to reduce odors, keep the latrine box clean, the seat lids closed, and the cracks sealed. Also, a good fly control program must be maintained in the area. The use of lime in the pit or the burning out of the pit contents is *not* effective for fly or odor control and should not be used. The box and the seats of the latrine should be scrubbed daily with soap and water. When a unit leaves the area or when deep pit

latrines are filled to within one foot of the ground surface, the latrines should be closed in the manner described in paragraph 3-2f.

d. **Bored-hole Latrines.** This type of latrine consists of a hole about 18 inches in diameter and from 15 to 20 feet deep that is covered by a one-hole latrine box (see Figure 3-4). The actual diameter is not critical; make it as large as available augers permit.

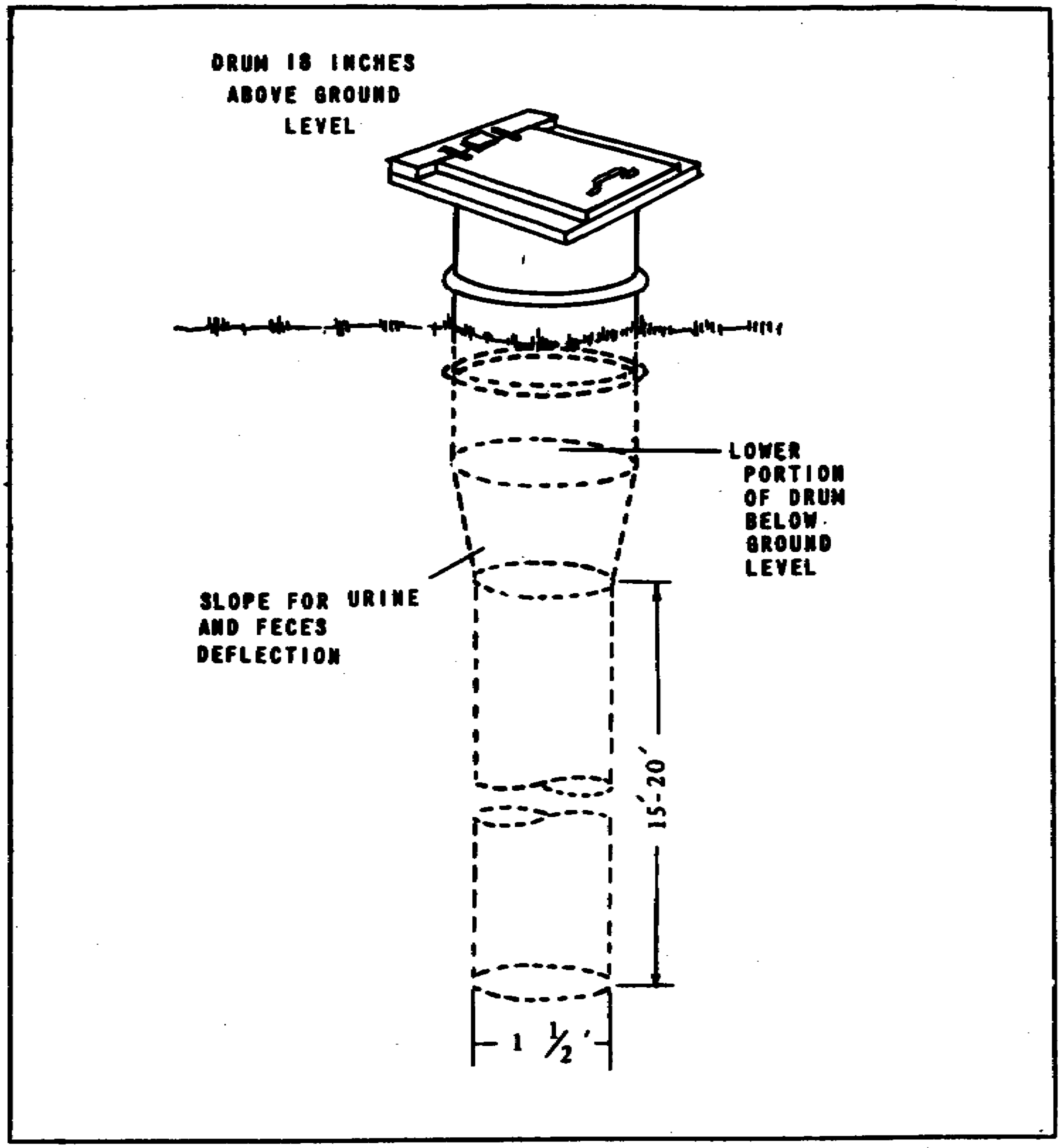


Figure 3-4. Bored-hole latrine.

(1) A covered metal drum may be sunk into the ground for use as a box. Both ends of the drum are removed and a flyproof seat cover with a self-closing lid is made to fit the top of the drum. If a drum is not available, a flyproof wooden box that is 18 inches in height may be constructed instead.

(2) This type of latrine is satisfactory for small units if the necessary mechanical equipment for boring the hole is available.

e. **Chemical Latrines.**

(1) Construction. These latrines or toilets may be used in the field when government or local policy permits. Chemical latrines are self-contained; meaning that they come equipped with a holding tank containing chemical additives to aid in the decomposition of the waste and control of the odor. The surgeon, preventive medicine personnel, or other AMEDD personnel establish the number of facilities required for the area.

(2) Sanitation. The latrines are to be cleaned daily. The contents are pumped as frequently as needed and disposed of by way of the conventional sanitary waste water system.

3-4. LATRINES USED IN HIGH WATER TABLE AREAS

Some of the latrines discussed in previous paragraphs are limited to areas in which the ground water table is deep enough to permit construction and use of the latrines without contaminating the ground water or having water standing in the latrine pit. For practical considerations, they are also limited to areas in which there is no impervious rock formation near the surface. In situations where the presence of a high water table or rock formation near the ground surface prevents the digging of a pit of adequate depth, several alternate methods are available.

a. **Mound Latrine.** A dirt mound makes it possible to build a deep pit latrine and still not have the pit extending into the water or the rock (see Figure 3-5).

(1) Construction. A mound of earth having a top at least 6 feet wide and 12 feet long should be constructed so that a 4-seat latrine box can be placed on its top. For 100 males, construction of one standard 4-seater is required (100 males x .04 = 4 males; 4 males/4 males per box = 1 box). For 100 females, construction of two standard 4-seaters is required (100 females x .06 = 6 females; 6 females/4 females per box =1.5 boxes; therefore, two 4-seaters are needed to accommodate 6 females at the same time). The mound should be high enough to meet the pit's requirement for depth, allowing 1 foot from the base of the pit to the water or the rock level. Before the mound is built, the area where it is to be placed should be broken up or plowed in order to aid seepage of liquids from the pit. If timber or wood is available, a crib of desired height is then built to enclose the pit and to help support the latrine box. The mound is then built and compacted in successive 1-foot layers until the top of the crib is reached as shown

in Figure 3-5. The surface of each layer is roughened before the next is added. If timber sufficient for building a crib is not available, the mound Is constructed to the desired height in 1-foot layers as described. The pit is then dug into the mound. It may be necessary to brace the walls with wood, sandbags, or other suitable material to prevent cave-ins. The size of the base of the mound will depend on the type of soil in the area and should be made larger if the slope is too steep. It may be necessary to build steps up the slope.

NOTE: Construction of latrines should be coordinated with the Corps of Engineers (COE).

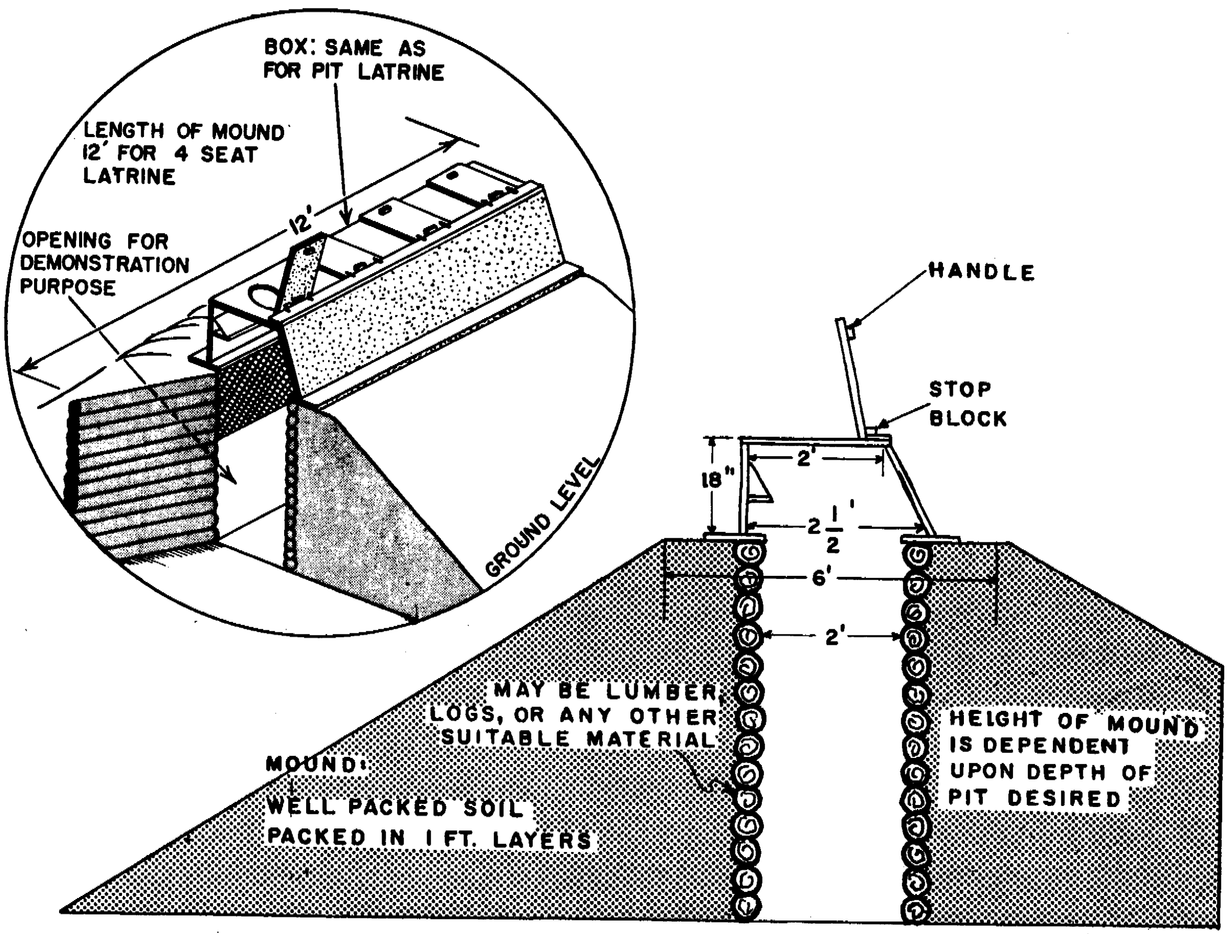


Figure 3-5. Mound latrine.

(2) Flyproofing and closing. The mound latrine should be fly-proofed in the same manner as is the deep pit latrine. It also is closed in the same manner, as is the deep pit latrine.

b. **Burn-Out Latrine.** The burn-out latrine (see Figure 3-6) is particularly suitable for jungle areas with high water tables, or when soil is rocky, hard, or frozen. It was particularly successful in some parts of Vietnam. It should not be used, however, when air pollution regulations prohibit open fires. For a unit of 100 men and 100 women, at least four men's latrines (100 x .04 = 4) and six women's latrines (100 x .06 = 6) are needed.

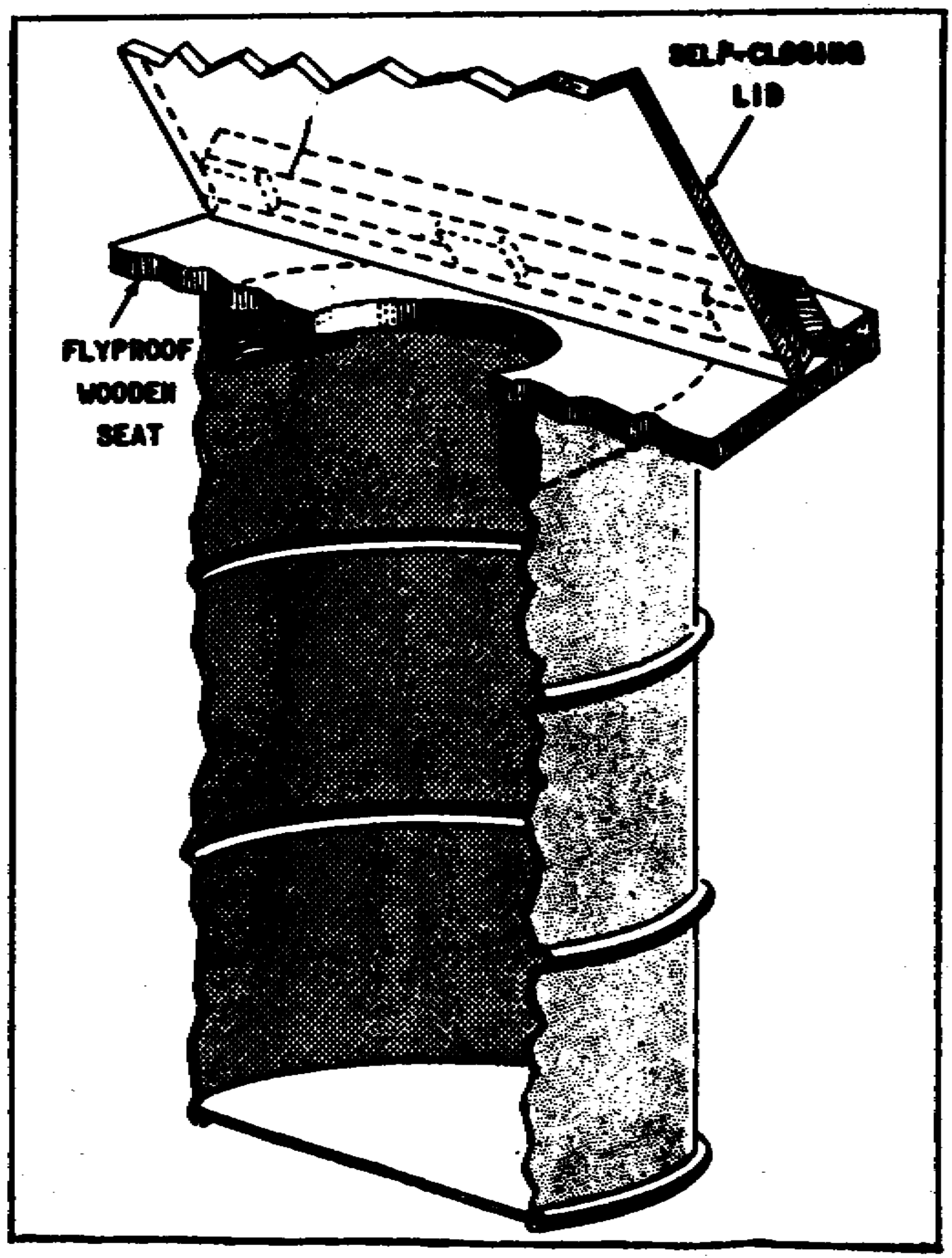


Figure 3-6. Burn-out latrine.

(1) Construction. A 55-gallon drum is placed into the ground, leaving enough of the drum above the ground for a comfortable sitting height.

(a) A wooden seat with a flyproof, self-closing lid is placed on top of the drum.

(b) If the drum must be moved to another site before the contents are burned out, handles should be welded to the sides to make it possible for two men to carry the drum with ease.

(c) It is convenient to have two sets of drums so that one set can be used while the other set is being burned clean.

(2) Sanitation. The burnout latrine should be burned out daily by adding sufficient fuel to incinerate the fecal matter.

CAUTION: Highly volatile fuel such as gasoline or JP4 should not be used because of its explosive nature.

(a) A mixture of 1 quart of gasoline to 4 quarts of diesel oil is effective; nevertheless, it should be used with caution.

(b) If contents are not rendered dry and odorless in one burning, they should be burned again. The residual ash should be buried.

NOTE: Male personnel should be encouraged to urinate in a urine disposal facility rather than in the burn-out latrine, as more fuel is required to burn out one with the liquid content.

c. **Pail or Bucket Latrine**. A pail latrine (see Figure 3-7) may be built when conditions (populated areas, rocky soil, marshes) are such that a dug latrine cannot be used.

(1) Construction. A standard type latrine box (para 3-5) may be converted for use as a pail latrine by placing hinged doors on the rear of the box, adding a floor, and placing a pail under each seat.

(a) If the box is located in a building, it should be placed to form a part of an outer wall so that the rear of the box opens directly to the outside of the building (see Figure 3-7 A). The seats and rear doors should be self-closing and the entire box flyproof.

(b) The floor of the box should be made of an impervious material (concrete, if possible) and should slope enough toward the rear to facilitate rapid drainage of washing water.

(c) A urinal may also be installed in the male latrine enclosure with a drainpipe leading to a pail outside. This pail also should be enclosed in a flyproof box.

(2) Sanitation. Pails should be cleaned at least once daily. The contents may be buried, burned, or disposed of by other sanitary methods. The use of plastic

liners for pails reduces the risk of accidental spillage. Filled bags are tied at the top, then disposed of by burning or burial.

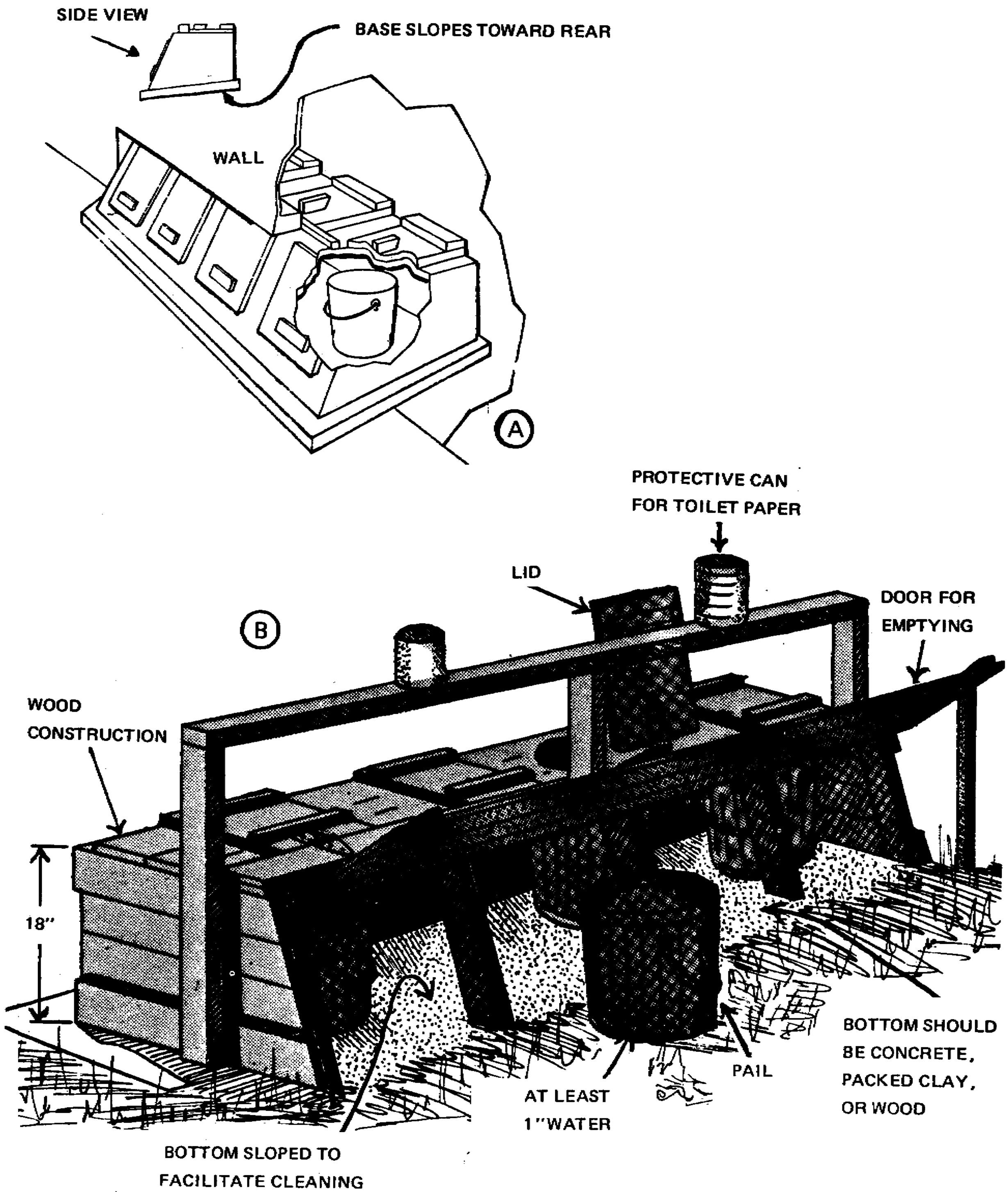


Figure 3-7. Pail latrine. (A) In a building. (B) In the open.

3-5. URINAL FACILITIES USED IN NORMAL WATER TABLE AREAS

In permanent and semipermanent camps, urine disposal facilities are usually connected into the wastewater collection system. In the field, separate devices for the disposal of urine may be necessary. Such facilities should be collocated in the male latrines to minimize fouling of seats. One urine disposal facility (more if needed) is required for each male latrine facility.

a. **Urine Soakage Pit**. The best device for urine disposal in the field is the urine soakage pit. However, for this disposal to function properly, soldiers must not urinate on the surface of the pit but into the extended pipes, funnels, etc.

(1) Construction. The pit is dug 4 feet square and 4 feet deep. It is then filled with rocks, flattened tin cans, broken bottles, or other coarse, contact material. A border 8 inches wide and 4 inches deep composed of small stones or similar material is laid along each edge of the pit such that each side of the soakage surface is 5 feet in length (see Figure 3-8). Depending on the materials available, either pipe, hose, or trough urinals may be used with this pit. These urinals are discussed below. An optional feature is the ventilating shafts with screened openings extending from about 6 inches above to within 6 inches of the bottom of the pit.

(2) Sanitation. Funnels or troughs must be cleaned daily with soap and water. Replace funnels as needed. Keep oil and grease away from the pit and funnels because they can clog them up. If the pit becomes clogged, spray it with a residual insecticide. These sanitary procedures apply to all urinals to be discussed. When the pit is no longer used, spray it with a residual insecticide and put a 2-foot covering of compacted, mounded dirt over it.

b. **Pipe Urinals**. Pipe urinals should be at least 1 inch in diameter. They should be placed at an angle near each corner of the pit and, if needed, on the sides halfway between corners (see Figure 3-8). These pipes should be about 36 inches long with at least 8 inches extending below the surface and 28 inches above the ground surface. A funnel of tar paper, sheet metal, or similar material is placed in the top of each pipe to make it easier to initially receive the liquid. The funnel is then covered with a screen to prevent insects and rodents from entering the pipe.

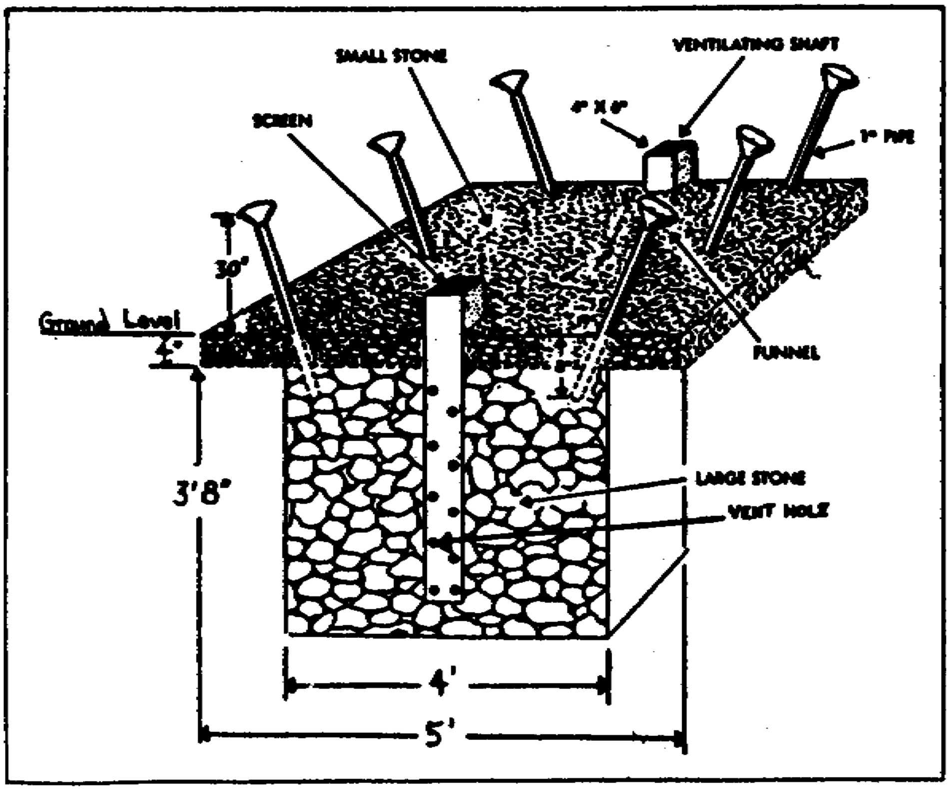


Figure 3-8. Urine soakage pit with pipe urinals.

c. **Trough Urinals.**

(1) Trough urinals. If wood and sheet metal are more readily available than pipe and a more permanent facility is desired, a trough urinal (see Figure 3-9) may be built. This 10 foot trough may be either U-or V-shaped and made of sheet metal or of wood. If wood is used, the trough should be lined with heavy tarpaper or metal. The legs at one end of the trough should be cut slightly shorter so the liquid will flow downward, into the pipe, and then into the soakage pit.

(2) Chemical latrine urinals. When troughs are included and attached to the inside wall of a chemical latrine, the pipe is connected to the trough to drain the liquid into the latrine holding tank.

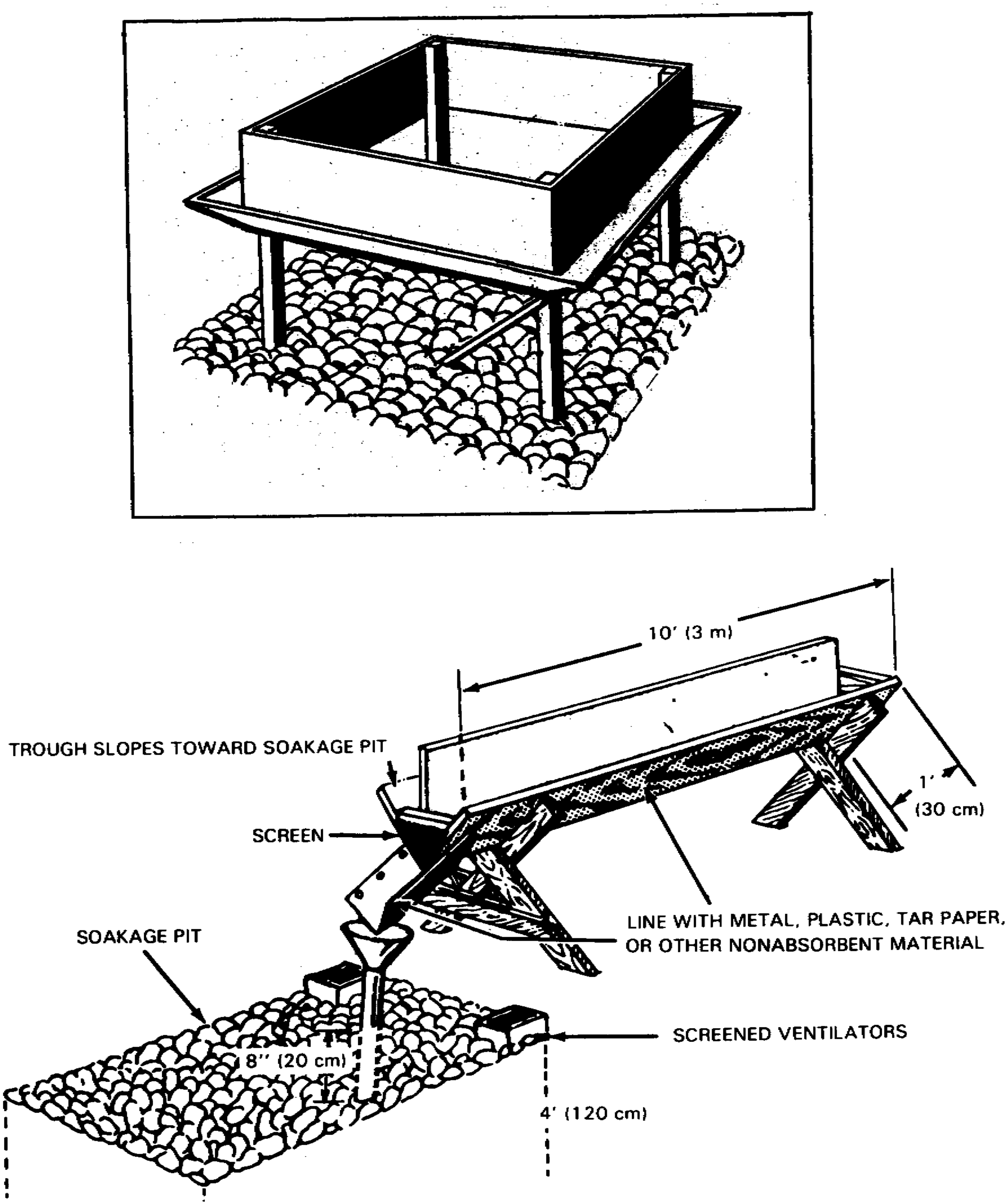


Figure 3-9. Trough urinals.

d. **Urinoil.** The urinoil (see Figure 3-10) represents a further modification for the more permanent installation. Simply described, it is a 55-gallon drum placed over a recessed soakage pit to receive and trap urine. The drum contains a quantity of waste oil, hence the name, urinoil. Urine voided through the screen and onto the surface of the oil immediately sinks through the oil to the bottom of the drum. The action of the urinoil is somewhat like that of a barometer. As more urine is added, the level rises within the 3-inch diameter pipe until it reaches the level of the notches in the 1 1/2-inch diameter overflow pipe in the center of the drum. The atmospheric pressure, together with the weight of the oil, causes the urine to overflow until equilibrium is reestablished within the drum. The oil acts as an effective seal against odors and against the entrance of flies. The screen is easily lifted with attached hooks for removal of debris. The urinoil is operative in place for as long as the soakage pit will accept the urine.

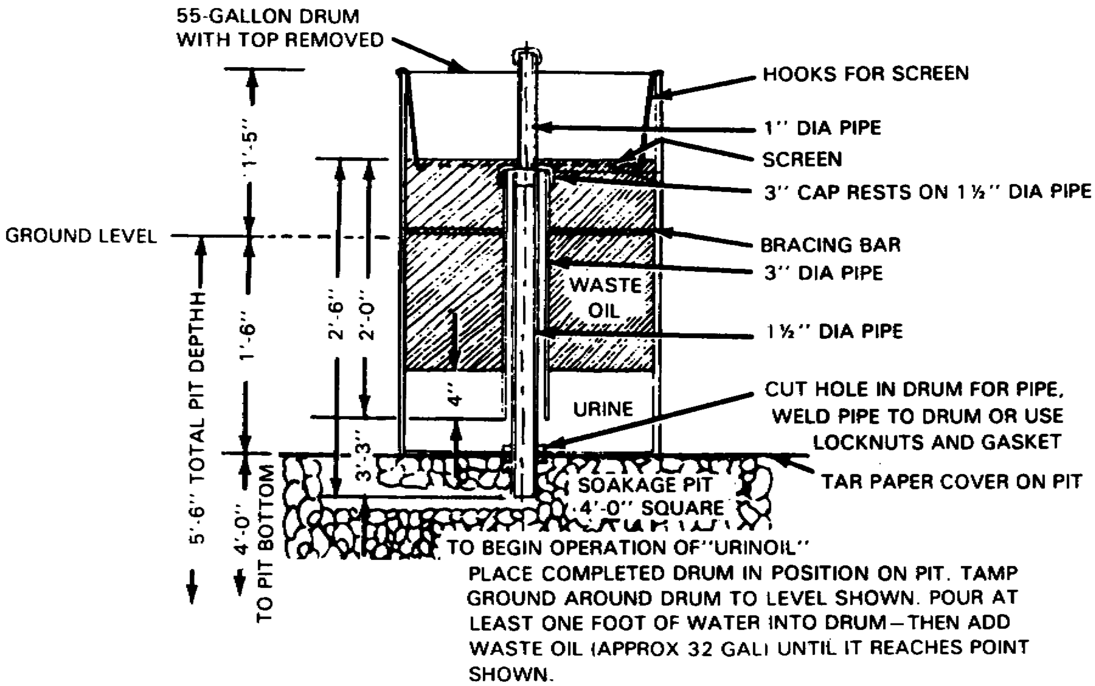


Figure 3-10. Urinoil urinal.

3-6. URINAL FACILITIES USED IN HIGH WATER TABLE OR ROCK FORMATION AREAS

When the water table or a hard rock formation near the surface precludes digging the standard 4 feet for a soakage pit, a soakage trench as described in paragraph 3-7b may be used in lieu of the soakage pit.

Section II. KITCHEN AND OTHER LIQUID WASTE DISPOSAL

3-7. KITCHEN WASTE FACILITIES

Liquid wastes from food service operations contain particles of food, grease, and soap. Consequently, this liquid requires treatment and/or removal before it is allowed to drain into a sewer or be disposed of by other means (para 1-l0d; see Figure 1-7). These facilities, along with the other liquid waste facilities, need to be close to the edge of the unit's area but at least 30 yards from the nearest water source.

a. **Soakage Pits.** In temporary camps, a soakage pit constructed like a urine soakage pit described in paragraph 3-5a will normally dispose of liquid kitchen wastes. The difference in the construction of urine soakage pits and kitchen waste soakage pits is that, in the kitchen waste soakage pit, a grease trap is substituted for the pipes or troughs used in the urine soakage pit. A company-sized unit of 200 soldiers would need two soakage pits so that each would have a rest period every other day to prevent the possibility of clogging by organic material. In porous soil, a soakage pit 4 feet square and 4 feet deep will take care of 200 gallons of liquid per day. In camps of long duration (7 weeks or more), two additional soakage pits would be constructed so that each would be given a rest period of 1 week every month to prevent clogging. A soakage pit that has become clogged will not accept additional liquid; it should be abandoned and a new one constructed. When such a pit is to be closed, it should be mounded over with 1 foot of compacted earth and properly marked (para 3-2f).

b. **Soakage Trench**. If the ground water level or a rock formation exists close to the surface, soakage trenches may be used in place of soakage pits. These trenches consist of a pit,2 feet square and 1 foot deep with a trench radiating outward from each of its sides for a distance of 6 feet or more (see Figure 3-11). These trenches are dug 1 foot wide and vary in depth from 1 foot at the central pit to 1 1/2 feet at the outer ends. The pit and trenches are filled with material similar to that used in the soakage pit. Two such units should be built for every 200 persons fed with each unit being used on alternate days. A grease trap should also be used with a soakage trench. A soakage trench is closed in a manner similar to closing a soakage pit.

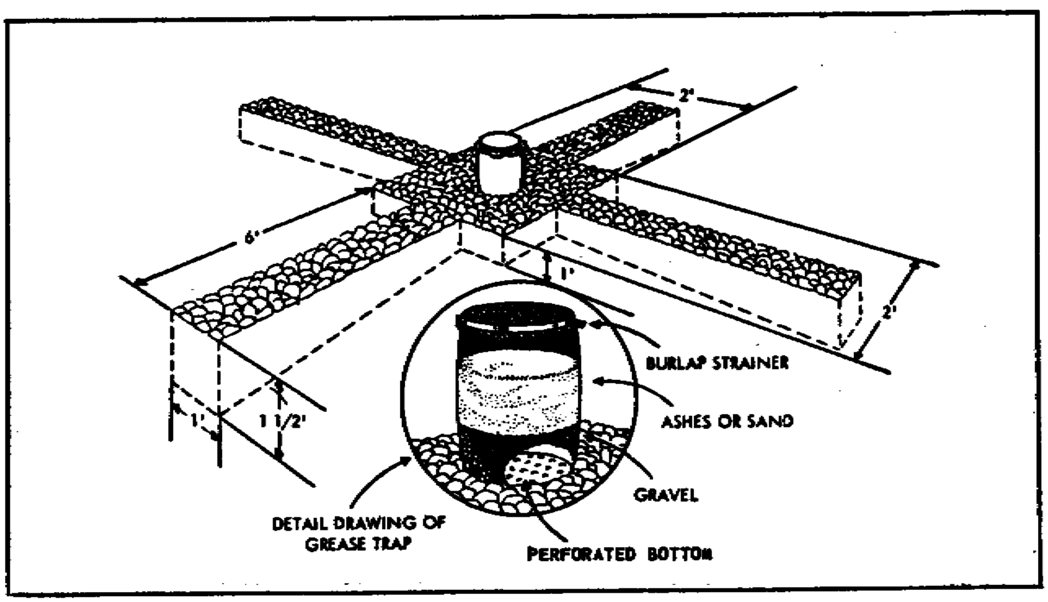


Figure 3-11. Soakage trench with barrel filter grease trap in place.

c. **Grease Traps.** The grease trap is a necessary addition to the kitchen soakage pit or trench. A grease trap should be of sufficient capacity so that hot, greasy water being added will not heat the cool water already present in the trap. Otherwise, the grease will remain uncongealed and pass through the trap instead of congealing and rising to the top of the water. A grease trap is provided for each soakage pit and trench, except those under showers. All kitchen liquid waste must pass through the grease trap to remove as much grease and food particles as possible in order to prevent the soakage pits from clogging. The Army uses two types of grease traps -- the baffle and the filter.

(1) Baffle grease trap. A baffle grease trap (see Figure 3-12) is the most effective way to remove grease.

(a) Construction. Before the liquid waste enters the entrance chamber of the baffle, it passes through a strainer that removes debris or solids and grease. The strainer is 2/3 full of loose straw, grass, or hay. The baffle is often a watertight barrel container; however, other objects may be used. The baffle may be a box or barrel that is divided vertically into unequal chambers by a wooden baffle. There are two chambers -- an entrance chamber and an exit chamber. The entrance chamber is twice as large as the exit chamber. The baffle should extend to within one inch of the bottom. The outlet consists of a 2-inch pipe placed 3 to 6 inches below the upper edge of the exit chamber. The container is placed on the ground along the soakage pit and the outlet pipe is extended 1 foot beneath the surface of the ground at the center of the pit (see Figure 3-12B). Before the baffle grease trap is used, the chambers are filled with cool water. When the warm liquid waste strikes the cool water in the entrance chamber, the grease rises to the surface and is prevented by the baffle from reaching the outlet to the soakage pit. The cool water keeps the grease buoyant and causes it to float to the top as a thick substance rather than as a thin or more liqidity form.

(b) Sanitation. The strainer material should be cleaned, changed, or replaced daily. The removable strainer may be cleaned by scrubbing it with soap and water as often as needed. Grease, sediment, and straining material should be either burned or buried. Grease collected in the entrance chamber should be skimmed from the surface of the water daily (or more frequently, if needed) to prevent clogging and then burned. Once grease is removed, the trap should be drained and the sediment in the bottom removed.

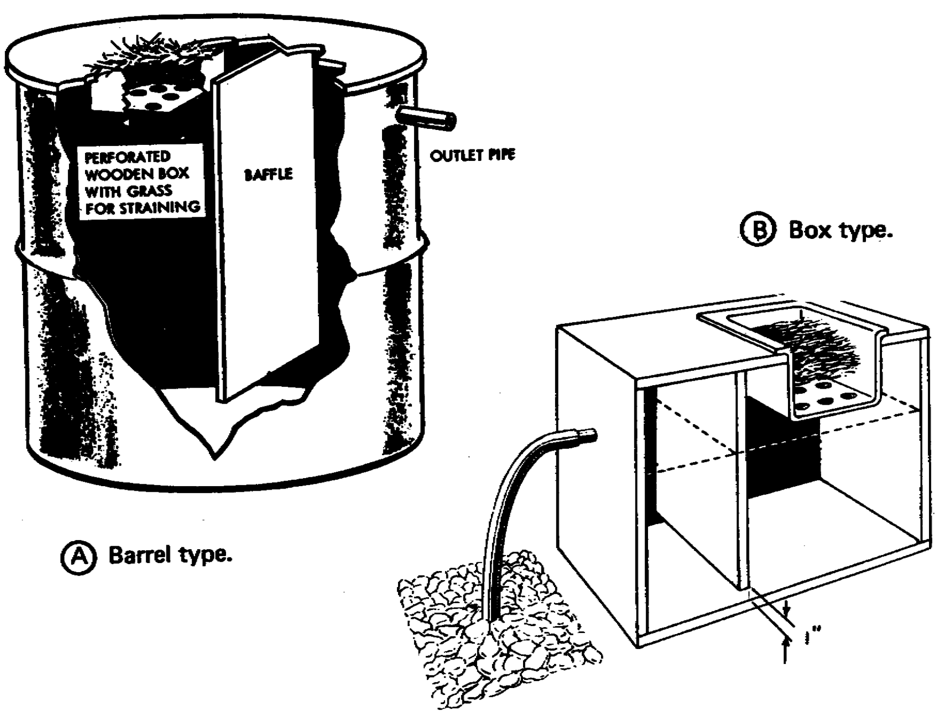


Figure 3-12. Baffle grease traps.

(2) Filter grease trap (barrel).

(a) Construction. The filter grease trap (see Figure 3-13) may be made from a 30- to 50-gallon barrel or drum which has had its top removed and a number of large holes bored into the bottom. The trap is placed directly over and in the center of the soakage pit with the bottom of the barrel about 2 inches below the surface of the pit. As an alternative, the barrel may be placed on a platform with a trough or pipe leading to the pit. In such a case, holes would not be made on the bottom of the barrel. Instead, one hole would be made 3/4 of the way up the barrel on the area closest to the pit and an outlet pipe placed in the hole. Regardless of the method, the bottom 2/3 of the barrel would be filled with large crushed rock or gravel, followed by smaller sized rock. Above the smaller rock, there should be 6 inches of filtering material such as sand, charcoal, ashes, or straw. A piece of burlap or other fabric is fastened to the top of the barrel to serve as a coarse strainer.

(b) Sanitation. Every day, the burlap is removed, then burned or buried and replaced with a clean one. Once or twice weekly, the 6-inch layer of filtering material is removed, buried, and replaced.

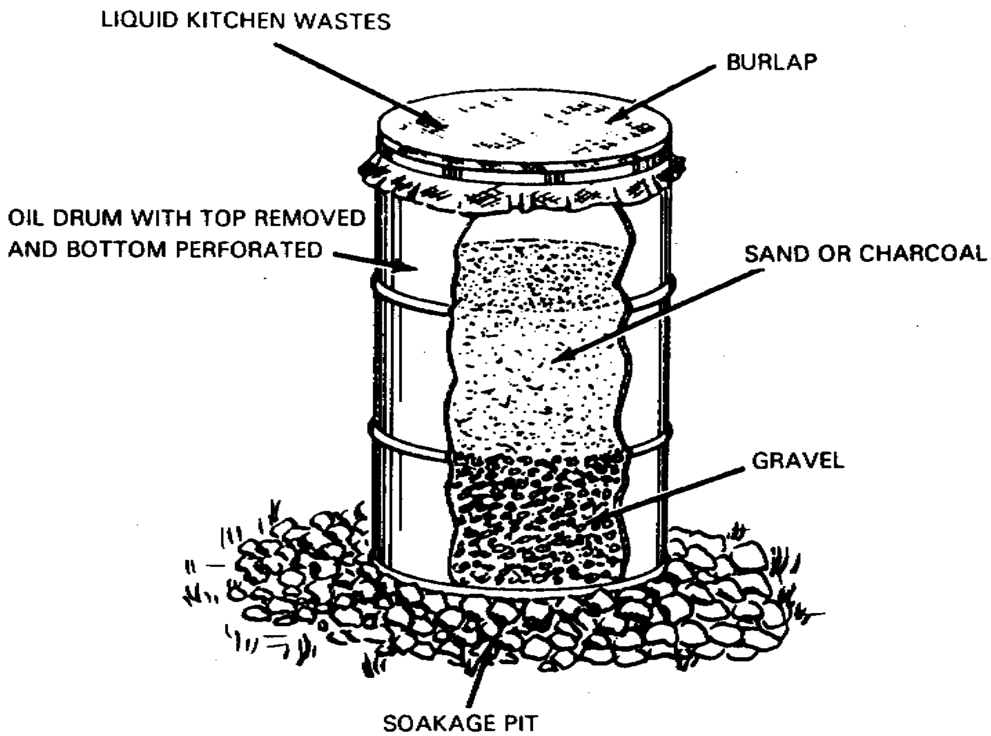


Figure 3-13. Filter grease trap.

d. **Evaporation Beds.** In places where clay soil prevents the use of standard soakage pits, evaporation beds (see Figure 3-14) may be used if climate is hot and dry.

(1) Construction. Sufficient 8 by 10 feet beds are constructed to allow 3 square feet of surface area per person per day for kitchen waste and 2 square feet per person per day for wash and bath wastes. The beds are to be spaced so that the wastes can be distributed to any one of the beds. In the construction of a bed, the top soil is first scraped off and piled up to form a small dike. Then the scraped earth within the bed is spaded to a depth of 10 to 15 inches and raked into a series of rows. The ridges are approximately 6 inches above the depression. These rows may be formed either lengthwise or crosswise as deemed desirable for best distribution of water.

(2) Operation. In operation, one bed is flooded during one day with liquid waste to the top of the ridges, which is equivalent to an average depth of 3 inches over the bed. The liquid waste is then allowed to evaporate and percolate. After 3 or 4 days, this bed is usually sufficiently dry for respading and reforming. The other beds are flooded on successive days with the same sequence of events being followed.

(3) Sanitation. Careful attention must be given to proper rotation, maintenance, and dosage of evaporation beds. It is also essential that the kitchen waste be run through an efficient grease trap (para 3-7) before it is allowed to enter the evaporation beds. If these beds are used properly, they create no insect hazard and

only a slight odor. Other modifications of waste disposal methods are possible and should be used when they are more adaptable to the particular situation.

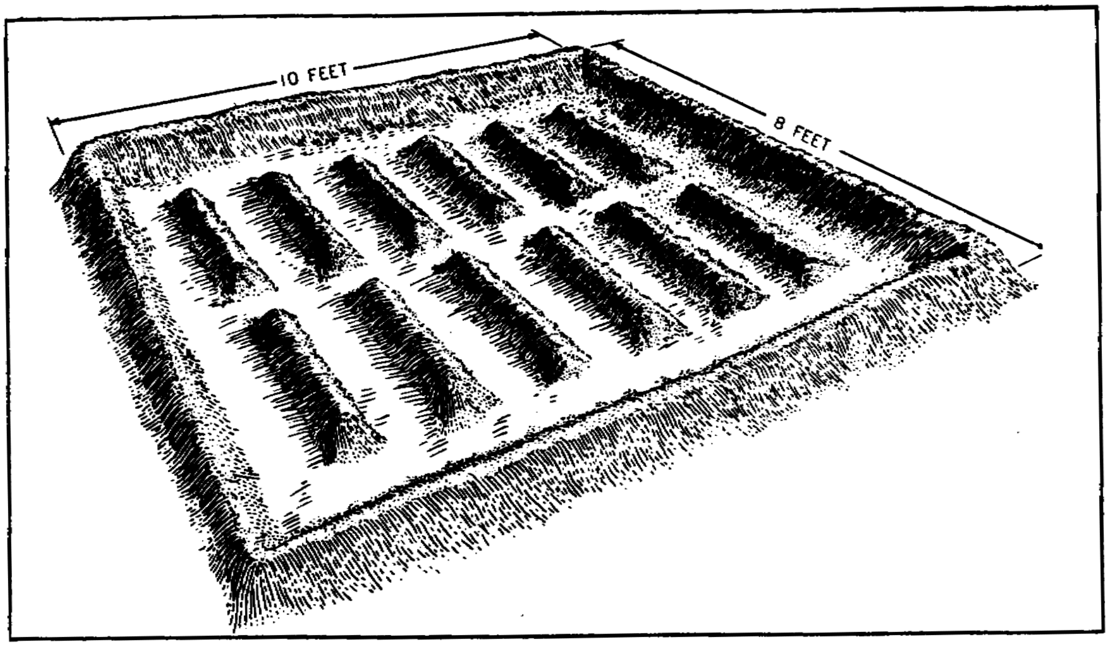


Figure 3-14. Evaporation bed.

3-8. OTHER WASTEWATER FACILITIES

a. **Noninfectious and Other Waste.** Every device that is used for washing or drinking in the field should have a soakage area of some kind under it to prevent pools and mud from forming.

(1) Construction. The area under and a few inches around individual handwashing devices, wash racks, and Lyster bags should be excavated a few inches and filled with small, smooth stones to form a soakage pit for spillage. Wastewater from wash racks should pass through a grease trap before it enters a soakage pit or soakage trench. A soakage pit or soakage trench should also be used with each field shower device; however, no grease trap is required under showers.

(2) Sanitation. The same sanitary principles should be followed as with a soakage pit or trench.

b. **Infectious Waste**.

(1) Types of infectious waste. Infectious liquid waste or waste which is potentially infectious includes sputum, surgical dressings, swabs, disposable diapers, culture media, pathological tissues, bloods clots and blood, live vaccine containers, syringes, and other materials from infectious patients.

NOTE: Although some of the items stated above are solid objects, they would probably contain liquid or dried liquid. It is for this reason that they are included as infectious liquid waste.

(2) Responsibility. The AMEDD is responsible for efficient, safe, and sanitary collection, storage, and disposal of infectious waste in the field in accordance with established Federal, state, and local laws or policies and applicable standing operating procedures. The AMEDD may handle this, train others to do it, or provide the guidance for commanders to do it. A central collecting point may be established or decentralized disposal may be used, depending on contingency plans or the situation.

(3) Methods of disposal.

(a) Bury. Infectious waste may be buried if the time, conditions, or situation does not warrant another method of disposal. However, a sign will be posted as previously described.

(b) Incinerate. Controlled incineration is the best method for disposing of medical waste; however, coordinate first for the specific type that will be burned.

1 Barrel incinerator. A barrel incinerator may be easily made to burn small amounts of infectious waste. The top of the barrel is removed and a grate is made by inserting scrap pipes into holes made at the lower sides of the bottom of the barrel or by removing the bottom of the barrel. The barrel may by set on a trench or supported on rocks, bricks, or cans filled with dirt to provide a upflow draft to keep the fire supplied with oxygen.

2 Inclined plane incinerator. The inclined plane incinerator (see Figure 3-15) is suitable for burning combustible and wet garbage. For good combustion, a fire is needed at the grate. As gasoline moves down from the drum, it flows into the lower pipe at the grate. The vapor burner heats the gasoline and causes it to vaporize in the upper pipe of the grate. This vapor produces pressure in the lower pipe and forces the fuel out through small holes as a spray, thus producing an extremely hot fire. If the burner is operated properly, a blue, extremely hot, flame will appear; otherwise, a yellow flame (which denotes incomplete burning) will show. A yellow flame can be adjusted to a blue flame by lowering the rate of flow in the line with the hand valve on the fuel container.

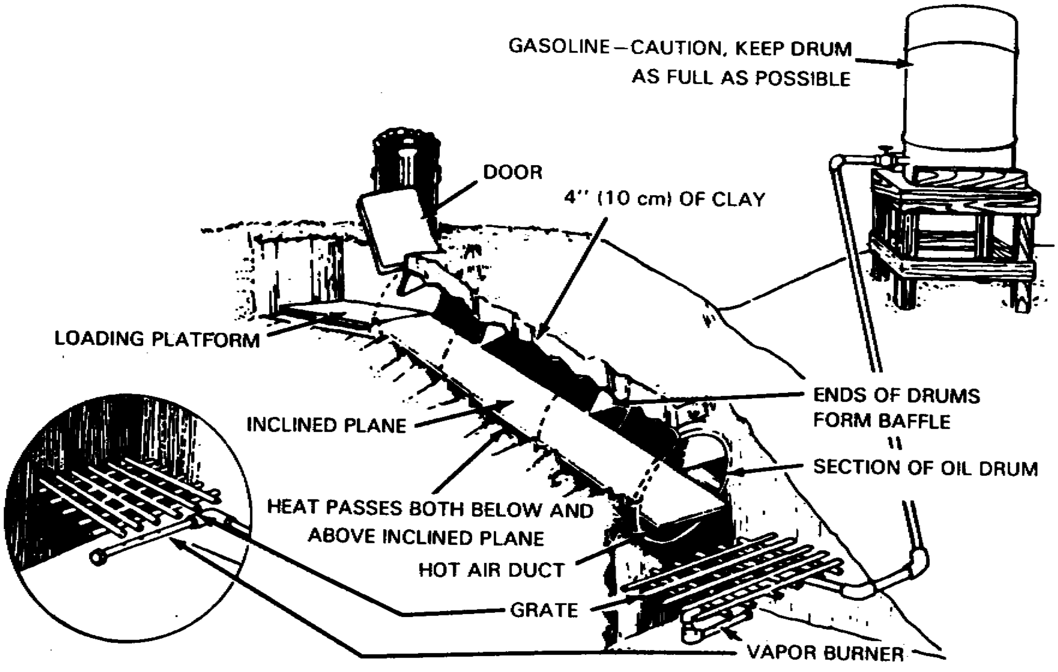


Figure 3-15. Inclined-plane incinerator with vapor burner.

Continue with Exercises

EXERCISES, LESSON 3

INSTRUCTIONS: Answer the following exercises by marking the lettered response that best answers the exercise, by completing the incomplete statement, or by writing the answer in the space provided at the end of the exercise.

After you have completed all these exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. Waste disposal under combat conditions is the responsibility of the:

   a. Surgeon.

   b. Engineer.

   c. Commander.

   d. Field sanitation team.

   e. Environmental health technician.

2. The individual soldier, who is away from his unit and has no latrine facilities available, disposes of his excreta by means of a ___________________.

3. A field latrine should be at least _______ yards from the unit dining facility.

4. A properly closed latrine will have a compacted layer of earth that is how thick? ___________________.

5. Which type of trench latrine is the most commonly used for temporary camps of 1 to 3 days' duration? _________________.

6. Field latrines should be adequate to accommodate ________ percent of the unit's male strength and __________ percent of the unit's female strength.

7. The construction of bored-hole latrines is limited by:

a. The equipment available.

b. The depth of the water table.

c. Impervious underground rock strata.

d. All of the above.

8. Which type of latrine is particularly suited to areas with high water tables?

a. Mound latrine.

b. Deep pit latrine.

c. Bored-hole latrine.

d. Straddle trench latrine.

9. What is the main factor in limiting the use of the burn-out latrine?

a. The weather.

b. Available fuel.

c. Air pollution regulations or ordinances.

d. Whether or not the latrine is in use at the time burning takes place.

10. What is the proper depth for a urine soakage pit? ____________________.

11. How often must urine soakage pit funnels or troughs be cleaned?
____

12. What causes urine to sink after it has been voided through the screen of a urinoil?
____

13. A soakage pit 4 feet wide, 4 feet long, and 4 feet deep will normally take care of kitchen liquids for _____________ soldiers for 1 day.

14. A soakage trench would be appropriate under the same conditions as a:

a. Soakage pit.

b. Bucket latrine.

c. Deep pit latrine.

d. Bored-hole latrine.

15. Grease traps are constructed on the principle that:

a. Fats are soluble in water.

b. Fats are lighter than water.

c. Fats and oils pass readily through porous materials.

d. Fats and oils separate readily from liquids when hot.

16. Which kitchen liquid waste disposal should be used if the soil is not sufficiently porous and the air is dry?

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 3

1. c (para 3-la)

2. Cat hole (para 3-3a)

3. 100 yards (para 3-2a)

4. 1 foot (para 3-2f)

5. Straddle trench latrine (para 3-3b)

6. 4;6 (para 3-2)

7. d (para 3-3d)

8. a (para 3-4a)

9. c (para 3-4b)

10. 4 feet (para 3-5a(1))

11. daily (para 3-5a(2))

12. oil (para 3-5d)

13. 200 (para 3-7a)

14. b (para 3-4c, 3-7b)

15. b (para 3-7c(1)(a))

16. Evaporation bed (para 3-7d)

End of Lesson 3

COMMENT SHEET

SUBCOURSE MD0164 Environmental Health Inspections and Surveys I **EDITION 100**

Your comments about this subcourse are valuable and aid the writers in refining the subcourse and making it more usable. Please enter your comments in the space provided. ENCLOSE THIS FORM (OR A COPY) WITH YOUR ANSWER SHEET **ONLY** IF YOU HAVE COMMENTS ABOUT THIS SUBCOURSE..

FOR A WRITTEN REPLY, WRITE A SEPARATE LETTER AND INCLUDE SOCIAL SECURITY NUMBER, RETURN ADDRESS (and e-mail address, if possible), SUBCOURSE NUMBER AND EDITION, AND PARAGRAPH/EXERCISE/EXAMINATION ITEM NUMBER.

PLEASE COMPLETE THE FOLLOWING ITEMS:

(Use the reverse side of this sheet, if necessary.)

1. List any terms that were not defined properly.

____
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2. List any errors.

<u>paragraph</u> <u>error</u> <u>correction</u>

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3. List any suggestions you have to improve this subcourse.

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